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Assignment

Electromagnetic Theory

PHYSICAL SCIENCES

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South Delhi Centre: 28-A/11, Jia Sarai, Near-IIT, Hauz Khas, New Delhi-16
T : 011-26851008, 26861009, (0) 9873744231, 9899628311

North Delhi Centre: 48, First Floor, Mall Road, G.T.B. Nagar (Metro Gate No.3), Delhi-09
T : 011-65462244, 27241845, (0) 9899628311, 9540292991
E: info@careerendeavour.com W: careerendeavour.com

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Assignment –I: Electromagnetic Theory

1. In a region of electrostatic field which of the following statements is true for a charged particle:
(a) There exists only one stable equilibrium point
(b) Many stable equilibrium points may exist.
(c) No stable equilirium point exists.
(d) Number of stable equilibrium points depends on how the field is produced

2. A shpere of radius R carrries a volume charge density $\rho = \rho_0 r$, where ρ_0 is a constant and r is the radial distance from the centre of the charged sphere. The intensity of the electric field is proportional to:

(a) r^2 for $r \le R$ and $1/r^2$ for $r \ge R$ (b) r for $r \le R$ and $1/r^2$ for $r \ge R$

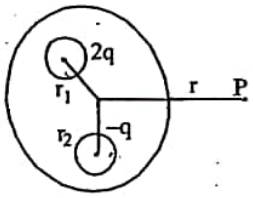
(c) $1/r^2$ for both $r \le R$ and $r \ge R$ (d) $1/r$ for $r \le R$ and $1/r^2$ for $r \ge R$

3. A uniformly charged thin spherical shell of radius R carries a total charge q. At a point inside (r < R) the spherical shell, if E and V are intensity of the electric field and electric potential respectively then:
(a) Both E and V are zero.
(b) E is zero but V is a nonzero constant.
(c) E is proportional to $1/r^2$ and V is proportional to 1/r.
(d) Both E and V are nonzero constants.

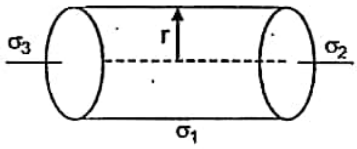
4. A spherical conductor of radius R has two cavities centered at r_1 and r_2 respectively from the centre of the conductor. The cavities contain point charges +2q and –q at their respective centers as shown in the figure. The magnitude of the electric field at a point P is:

(a) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ (b) $\frac{1}{4\pi\varepsilon_0}\left[\left(\frac{2q}{(r-r_1)^2}\right)^2+\left(\frac{-q}{(r-r_2)^2}\right)^2\right]^{1/2}$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-r_1-r_2)^2}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-r_1)^2+(r-r_2)^2}$



5. A cylinder of radius R and length L carries a polarization $\mathbf{P} = P_0\bar{r}$, where P_0 is a constant and $\bar{r}$ is a radial vector from the axis. The surface bound charges on the cylindrical surface (σ_1) and at the circular surfaces $(\sigma_2$ and $\sigma_3)$ as shown in the firgure are:



(a) $\sigma_1 = 0, \sigma_2 = \sigma_3 = P_0R$ (b) (b) $\sigma_1 = P_0R, \sigma_2 = \sigma_3 = 0$

(c) $\sigma_1 = P_0R^2/L, \sigma_2 = \sigma_3 = P_0R$ (d) $\sigma_1 = P_0R, \sigma_2 = \sigma_3 = P_0R^2/L$

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6. **STATEMENT I :**
The work done by the magnetic force on a moving charged particle is zero.
STATEMENT II :
The magnetic force tends to change the direction of a moving charged particle in a direction perpendicular to both the magnetic field and the instantaneous velocity of the particle.
(a) Statements I and II both are ture. Statement II is the correct explanation for statement I.
(b) Statements I and II both are true. Statement II is not the correct explanation for statement I.
(c) Statement I is true but statement II is false.
(d) Statement I is false but statement II is true

7. A dipole of magnetic moment $\vec{m}$ is placed in an inhormogeneous magnetic field $\vec{B}$. The force experienced by the dipole is :
(a) $\vec{F}=\vec{m}\times(\vec{\nabla}\times\vec{B})$ (b) $\vec{F}=(\vec{m}.\vec{\nabla})\vec{B}$ (c) $\vec{F}=(\vec{\nabla}.\vec{m})\vec{B}$ (d) $\vec{F}=\vec{\nabla}\times(\vec{m}\times\vec{B})$

8. An electro-magnetic field is defined by a scalar potential $\phi(\vec{r},t)=0$ and vector potential $\vec{A}(\vec{r},t)=\frac{1}{4\pi\varepsilon_0}\frac{qt}{r^2}\hat{r}$. The corresponding electric field is :
(a) $\vec{E}=0$ (b) $\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (c) $\vec{E}=-\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (d) $\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{\theta}$

9. Which one of the following current densities, $\vec{j}$, can generate the magnetic vector potential $\vec{A}=(y^2\hat{i}+x^2\hat{j})$?
(a) $\frac{2}{\mu_0}(x\hat{i}+y\hat{j})$ (b) $-\frac{2}{\mu_0}(\hat{i}+\hat{j})$ (c) $\frac{2}{\mu_0}(\hat{i}-\hat{j})$ (d) $\frac{2}{\mu_0}(x\hat{i}-y\hat{j})$

10. In a non-conducting medium characterized by $\varepsilon=\varepsilon_0, \mu=\mu_0$ and conductivity $\sigma=0$, the electric field $(\text{in } Vm^{-1})$ is given by $\vec{E}=20\sin[10^8t-kz]\hat{j}$. The magnetic field, $\vec{H}(\text{in } A\,m^{-1})$, is given by :
(a) $20k\cos[10^8t-kz]\hat{i}$ (b) $\frac{20k}{10^8\mu_0}\sin[10^8t-kz]\hat{j}$
(c) $-\frac{20k}{10^8\mu_0}\sin[10^8t-kz]\hat{i}$ (d) $-20k\cos[10^8t-kz]\hat{j}$

Statement for Linked Answer Q.11 and Q.12 :
A dielectric sphere of radius R carries polarization $\vec{P}=kr^2\hat{r}$, wherer r is the distance from the centre and k is a constant. In the spherical polar coordinate system, $\hat{r}, \hat{\theta}$ and $\hat{\varphi}$ are the unit vectors.

11. The bound volume charge density inside the sphere at a distance r from the centre is :
(a) $-4kR$ (b) $-4kr$ (c) $-4kr^2$ (d) $-4kr^3$

12. The electric field inside the sphere at a distance d from the centre is :
(a) $\frac{-kd^2}{\varepsilon_0}\hat{r}$ (b) $\frac{-kR^2}{\varepsilon_0}\hat{r}$ (c) $\frac{-kd^2}{\varepsilon_0}\hat{\theta}$ (d) $\frac{-kR^2}{\varepsilon_0}\hat{\theta}$

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13. Which one of the following sets of Maxwell's equations for time - independent charge density ρ and current density $\hat{J}$ is correct?

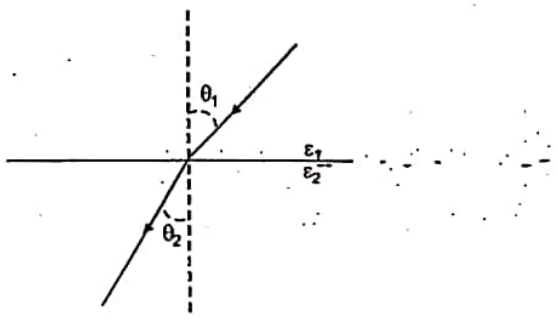
(a) $\vec{\nabla}.\vec{E}=\rho/\varepsilon_0$, $\vec{\nabla}.\vec{B}=0$, $\vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}$, $\vec{\nabla}\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$

(b) $\vec{\nabla}.\vec{E}=\rho/\varepsilon_0$, $\vec{\nabla}.\vec{B}=0$, $\vec{\nabla}\times\vec{E}=0$, $\vec{\nabla}\times\vec{B}=\mu_0\hat{J}$

(c) $\vec{\nabla}.\vec{E}=0$, $\vec{\nabla}.\vec{B}=0$, $\vec{\nabla}\times\vec{E}=0$, $\vec{\nabla}\times\vec{B}=\mu_0\hat{J}$

(d) $\vec{\nabla}.\vec{E}=\rho/\varepsilon_0$, $\vec{\nabla}.\vec{B}=\mu_0\hat{J}$, $\vec{\nabla}\times\vec{E}=0$, $\vec{\nabla}\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$

14. At the interface between two linear dielectrics (with dielectric constants ε_1 and ε_2), the electric field lines bend, as shown in the figure. Assume that there are no free charges at the interface. The ratio ε_1 and ε_2 is :



(a) $\frac{\tan\theta_1}{\tan\theta_2}$ (b) $\frac{\cos\theta_1}{\cos\theta_2}$ (c) $\frac{\sin\theta_1}{\sin\theta_2}$ (d) $\frac{\cot\theta_1}{\cot\theta_2}$

15. The vector potential in a region is given as $\vec{A}(x,y,z)=-y\hat{i}+2x\hat{j}$. The associated magnetic induction is $\vec{B}$ is :

(a) $\hat{i}+\hat{k}$ (b) $3\hat{k}$ (c) $-\hat{i}+2\hat{j}$ (d) $-\hat{i}+\hat{j}+\hat{k}$

16. Three point charges q, q and $-2q$ are located at $(0,-a,a)$, $(0,a,a)$ and $(0,0,-a)$ and $(0,0,-a)$, respectively. The net dipole moment of this charge distribution is :

(a) $4qa\hat{k}$ (b) $2qa\hat{k}$ (c) $-4qa\hat{i}$ (d) $-2qa\hat{j}$

17. A shere of radius R has uniform volume charge density. The electric potential at a point r (r<R)is
(a) Due to the charge inside a sphere of radius r only
(b) Due to the entire charge of the sphere
(c) Due to charge in the spherical shell of inner and outer radii r and R, only
(d) Independent of r

18. In an electromagnetic field, which one of the following remains invariant under Lorentz transformation?

(a) $\vec{E}\times\vec{B}$ (b) $E^2-c^2B^2$ (c) B^2 (d) E^2

19. The value of $\oint_c \vec{A}.d\vec{\ell}$ along a square loop of side L in a uniform field $\vec{A}$ is :

(a) 0 (b) 2LA (c) 4LA (d) L^2A

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20. For a vector potential $\vec{A}$, the divergence of $\vec{A}$ is $\vec{\nabla}.\vec{A}=-\frac{\mu_0}{4\pi}\frac{Q}{r^2}$, where Q is a constant of appropriate dimension. The corresponding scalar potential $\varphi(\vec{r},t)$ that makes $\vec{A}$ and φ Lorentz gauge invariant is :

(a) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{Qt}{r}$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{Qt}{r^2}$

21. The work done in bringing a charge +q from infinity in free space, to a position at a distance d in front of a semi-infinite grounded metal surface is :

(a) $-\frac{q^2}{4\pi\varepsilon_0(d)}$ (b) $-\frac{q^2}{4\pi\varepsilon_0(2d)}$ (c) $-\frac{q^2}{4\pi\varepsilon_0(4d)}$ (d) $-\frac{q^2}{4\pi\varepsilon_0(6d)}$

22. If the electrostatic potential were given by $\phi=\phi_0\left(x^2+y^2+z^2\right)$, where ϕ_0 is constant, then the charge density giving rise to the above potential would be :

(a) 0 (b) $-6\phi_0\varepsilon_0$ (c) $-2\phi_0\varepsilon_0$ (d) $-\frac{6\phi_0}{\varepsilon_0}$

23. A solid sphere of radius R carries a uniform volume charge density ρ. The magnitude of electric field inside the sphere at a distance r from the centre is :

(a) $\frac{r\rho}{3\varepsilon_0}$ (b) $\frac{R\rho}{3\varepsilon_0}$ (c) $\frac{R^2\rho}{r\varepsilon_0}$ (d) $\frac{R^3\rho}{r^2\varepsilon_0}$

24. A Plane electromagnetic wave of frequency ω is incident normally on an air-dielectric interface. He dielectric is linear, isotropic, non-magnetic and its refractive index is n. The reflectance (R) and transmittance (T) from the interface are :

(a) $R=\left(\frac{n-1}{n+1}\right)^2, T=\frac{4n}{(n+1)^2}$ (b) $R=-\left(\frac{n-1}{n+1}\right), T=\frac{2}{(n+1)^2}$

(c) $R=\left(\frac{n-1}{n+1}\right)^3, T=\frac{4n^3}{(n+1)^3}$ (d) $R=\left(\frac{(n-1)^2}{n+1}\right), T=\frac{4n^2}{(n+1)^2}$

25. A conducting sphere of radius R has charge + Q on its surface. If the charge on the sphere is doubled and its radius is halved, the energy associated with the electric field will :

(a) Increase four times (b) Increase eight times
(c) Remain the same (d) Decrease four times

26. A charge + q is kept at a distance of 2R from the center of a grounded conducting sphere of radius R. The image charge and its distance from the centre are, respectively :

(a) $-\frac{q}{2}$ and $\frac{R}{2}$ (b) $-\frac{q}{2}$ and $\frac{R}{4}$ (c) $-q$ and $\frac{R}{2}$ (d) $+\frac{q}{2}$ and $\frac{R}{2}$

27. An infinite conducting sheet in the x-y plane carries a surface current density K along the y-axis. The magnetic field B for z > 0 is :

(a) B = 0 (b) $B=\mu_0 K\hat{k}/z$ (c) $B=\mu_0 K\hat{i}/2$ (d) $B=\mu_0 K.\hat{j}/\left(x^2+z^2\right)^{0.5}$

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28. The dielectric constant of water is 80. However its refractive index is 1.75 invalidating the expression $n = \varepsilon^{1/2}$. This is because
(a) The water molecule has a permanent dipole moment
(b) The boiling point of water is 100°C
(c) The two quantities are measured in different experiments
(d) Water is transparent to visible light

29. An electromagnetic wave is propagating in free space in the z-direction. If the electric field is given by $E = \cos(\omega t - kz)i$, where $\omega t = ck$, then the magnetic field is given by :

(a) $B = (1/c)\cos(\omega t - kz)j$ (b) $B = (1/c)\sin(\omega t - kz)j$

(c) $B = (1/c)\cos(\omega t - kz)i$ (d) $B = (1/c)\cos(\omega t - kz)ji$

30. Which one of the following Maxwell's equations implies the absence of magnetic monopoles?

(a) $\nabla.E = \pi/\varepsilon_0$ (b) $\nabla.B = 0$

(c) $\nabla \times E = -\partial B/\partial t$ (d) $\nabla \times B = (1/c^2)\partial B/\partial t + \mu_0 J$

31. In a two beam interference pattern, the maximum and minimum intensity values are found to be $25\,I_0$ and $9\,I_0$ respectively, where I_0 is a constant. The intensities of the two interfereing beams are :

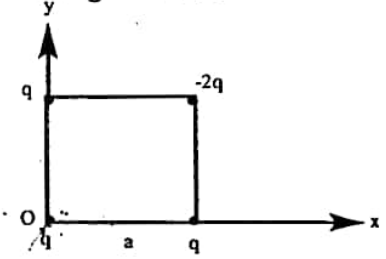
(a) $16\,I_0$ and I_0 (b) $5\,I_0$ and $3\,I_0$ (c) $17\,I_0$ and $8\,I_0$ (d) $8\,I_0$ and $2\,I_0$

32. A left circularly polarized light beam of wavelength 600 nmis incident on a crystal of thickness d and propagated perpendicular to its optic axis. The ordinary and extraordinary refractive indices of the crystal are $n_0 = 1.54$ and $n_e = 1.55$ respectively. The emergent light will be right circularly polarized if d is :

(a) 120 μm (b) 60 μm (c) 30μm (d) 15μm

33. An infinitely long closely would solenoid carries a sinusoidally varying current. The induced electric field is :
(a) Zero everywhere
(b) Non-zero inside and zero outside the solenoid
(c) Non-zero inside as well as outside the solenoid
(d) Zero inside and non-zero outside the solenoid

34. Four charges are placed at the four corners of a square of side a as shown in the figure. The electric dipole moment of this configuration is :



(a) $\vec{p} = qa\hat{i} + qa\hat{j}$ (b) $\vec{p} = -qa\hat{i} + qa\hat{j}$

(c) $\vec{p} = -qa\hat{i} - qa\hat{j}$ (d) $\vec{p} = qa\hat{i} - qa\hat{j}$

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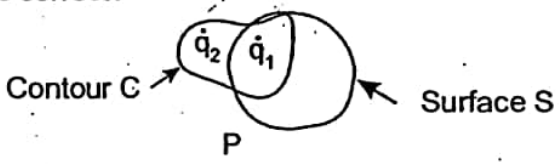
35. Consider a set of two stationary point charges q_1 and q_2 as shown in the figure. Which of the following statements is correct?



(a) The electric field at P is independent of q_2
(b) The electric flux crossing the closed surface S is independent of q_2
(c) The line integral of the electric field $\vec{E}$ over the closed contour C depends on q_1 and q_2.
(d) $\vec{\nabla}.\vec{E}=0$ everywhere

36. Consider an infinitely long straight cylindrical conductor of radius R with its axis along the z-direction, which carries a current of 1 A uniformly distributed over its cross section. Which of the following statements is correct?

(a) $\vec{\nabla}\times\vec{B}=0$ everywhere
(b) $\vec{\nabla}\times\vec{B}=\frac{\mu_0}{\pi R^2}\hat{z}$ everywhere
(c) $\vec{\nabla}\times\vec{B}=0$ for $r>R$
(d) $\vec{\nabla}\times\vec{B}=\frac{\mu_0}{\pi R^2}\hat{z}$ for $r>R$

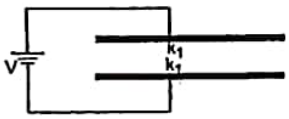
where r is the radial distance from the axis of the cylinder.

37. Consider an electric field $\vec{E}$ existing in the interface between a conductor and free space. Then the electric field $\vec{E}$ is :
(a) External to the conductor and normal to the conductor's surface
(b) Internal to the conductor and normal to the conductor's surface
(c) External to the conductor and tangential to the conductor's surface
(d) Both external and internal to the conductor and normal to the conductor's surface

38. Two point charges $Q_1 = 1$ nC and $Q_2 = 2$ nC are kept in free space such that the distance between them is 0.1 m.
(a) The force on Q_2 is along the direction from Q_2 to Q_1
(b) The force on Q_2 is the same in magnitude as that on Q_1
(c) The force on Q_1 is attractive
(d) A point charge $Q_3 = -3$ nC, placed at the midpoint between Q_1 and Q_2, experiences no net force.

39. A very long solenoid with n turns per unit length carries a current I. The magnetic field at a point, which is on its axis and its end face, is :
(a) $\mu_0 nI$ (b) $(2/3)\mu_0 nI$ (c) $(1/3)\mu_0 nI$ (d) $(1/2)\mu_0 nI$

40. The space between the plates of a parallel plate capacitor is filled with two dielectric slabs of dielectric constants k_1 and k_2 as shown in the figure. If the capacitor is charged to a potential V, then at the interface between the two dielectrics.
(a) $\vec{E}$ is discontinuous and $\vec{D}$ is continuous
(b) $\vec{E}$ is discontinuous and $\vec{D}$ is discontinuous
(c) $\vec{E}$ is continuous and $\vec{D}$ is continuous
(d) $\vec{E}$ is continuous and $\vec{D}$ is discontinous



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Common data for Q. 41 and Q.42.

Consider two concentric conducting spherical shells with inner and outer radii a, b and c, d as shown in the figure. Both the shells are given Q amount of positive charges.

41. The electric field in different regions are :

(a) $\vec{E}=0$ for $r<a$; $\vec{E}=\frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $a<r<b$; $\vec{E}=0$ for $b<r<c$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r>d$

(b) $\vec{E}=\frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r<a$; $\vec{E}=0$ for $a<r<b$, $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $b<r<c$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r<d$

(c) $\vec{E}=\frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r<a$; $\vec{E}=0$ for $a<r<b$, $\vec{E}=0$ $b<r<c$; $\vec{E}=\frac{2Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r>d$

(d) $\vec{E}=0$ for $r>a$; $\vec{E}=0$ for $a<r<b$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $b<r<c$; $\vec{E}=\frac{2Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r>d$

42. In order to have equal surface charge densities on the outer surfaces of both the shells, the following conditions should be satisfied

(a) $d=4b$ and $c=2a$ (b) $d=2b$ and $c=\sqrt{2}a$

(c) $d=\sqrt{2}b$ and $c>a$ $d=\sqrt{2}b$ (d) $d>b$ and $c=\sqrt{2}a$

43. Consider an infinite line charge with linear charge density λ. At a distance r from the line, the electrostatic potential has the form

(a) $\frac{\lambda a}{4\pi\varepsilon_0 r}$ (b) $\frac{\lambda}{4\pi\varepsilon_0}\exp(-r/a)$ (c) $\frac{\lambda}{4\pi\varepsilon_0}\ln(r/a)$ (d) $\frac{\lambda}{4\pi\varepsilon_0}\frac{r}{a}$

44. A thin dielectric slab is slowly introduced between the plates of a charged parallel plate capacitor, as shown in the figure.

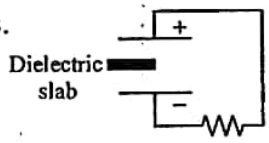
Which of the following is true?

(a) The slab is pushed out of the region between the capacitor plates.

(b) The slab is sucked into the region between the capacitor plates.

(c) The slab moves towards the positively charged plate.

(d) The slab moves towards the negatively charged plate.



45. If in interior of a unit sphere we have $\vec{\nabla}.\vec{J}=a$ positive constant, where $\vec{J}$ is the current density then we may conclude that;

(a) According to Gauss' theorem, the charge contained in the unit sphere is constant in time.

(b) According to Gauss' theorem, charge is flowing into the unit sphere.

(c) According to the continuity equation, the charge density within the unit sphere must necessarily be uniform.

(d) According to the continuity equation, the change density inside the unit sphere diminishes with time.

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46. Choose the correct statement from the following:
(a) The magnetic field $\vec{B}$ is a vector and not a pseudovector.
(b) $\vec{E}.\vec{B}$ is a scalar and not a pseudoscalar.
(c) $\vec{E}\times\vec{B}$ is a pseudovector.
(d) The magnetic vector potential $\vec{A}$ is a pseudovector.

47. Consider the operations $P:\vec{r}\to-\vec{r}\,(\text{parity})$ and $T:t\to-t$ (time-reversal). For the electric and magnetic field $\vec{E}$ and $\vec{B}$, which of the following set of transformations is correct?

(a) $P:\vec{E}\to-\vec{E},\vec{B}\to\vec{B};\ T:\vec{E}\to\vec{E},\vec{B}\to-\vec{B}$
(b) $P:\vec{E}\to\vec{E},\vec{B}\to\vec{B};\ T:\vec{E}\to\vec{E},\vec{B}\to\vec{B}$
(c) $P:\vec{E}\to\vec{E},\vec{B}\to\vec{B};\ T:\vec{E}\to-\vec{E},\vec{B}\to-\vec{B}$
(d) $P:\vec{E}\to\vec{E},\vec{B}\to-\vec{B};\ T:\vec{E}\to-\vec{E},\vec{B}\to\vec{B}$

48. A charged particle moving with a constant velocity enters a magnetic field perpendicular to its velocity. In which direction y an electric field should be applied to compensate the magnetic force?
(a) Along the initial velocity
(b) Perpendicular to the initial velocity and parallel to the magnetic field.
(c) Perpendicular to both, the initial velocity and the magnetic field.
(d) Along the magnetic field.

49. The neutral pion π^0 at rest decays into two photons. One of the photons is right circularly polarized. The other photon is:
(a) Also right circularly polarized.
(b) Left circularly polarized.
(c) Unpolarized.
(d) Plane polarized.

50. Consider a parallel plate capacitor connected to an AC voltage source (as shown in fig.1). A conducting slab is introduced in the space between the plates from above (as shown in fig.2)

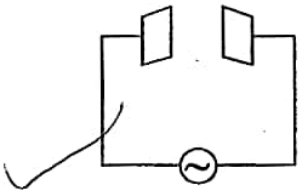

Fig. 1

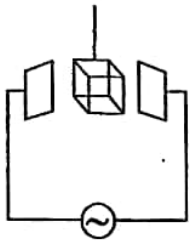

Fig. 2

The capacitance of the parallel plate capacitor.
(a) Goes to zero.
(b) Increases to a finite value.
(c) Decreases to a non-zero value.
(d) Becomes infinite.

51. When a particle of charge q is at rest, it produces
(a) Only electric field
(b) Only magnetic field
(c) Both electric and magnetic fields.
(d) A magnetic field depending upon the sign of the charge.

52. A charge q is revolving with angular velocity ω in a plane perpendicular to a uniform magnetic field B. If the field is reduced to B/2.
(a) The linear velocity is doubled
(b) The linear velocity is halved
(c) The radius is halved
(d) The radius is doubled.

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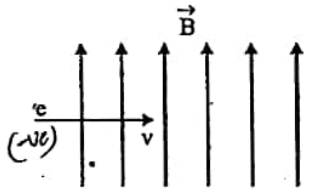
53. An electromagnetic wave is normally incident upon a perfectly conducting surface. In the reflected wave,
(a) $\bar{H}$ is shifted 180° in phase.
(b) $\bar{E}$ is shifted 180° in phase
(c) $\bar{H}$ is shifted 90° in phase
(d) $\bar{E}$ is shifted 90° in phase.

54. The condition for a vector potential $\bar{A}$ to satisfy the wave equation is:
(a) $\bar{\nabla}.\bar{A}=0$
(b) $\bar{\nabla}.\bar{A}+\mu_0 \in_0 \frac{\partial \phi}{\partial t}=0$
(c) $\frac{\partial \bar{A}}{\partial t}+\mu_0 \in_0 \bar{\nabla}\phi=0$
(d) $\bar{A}+\bar{\nabla}\phi=0$

55. A stream of electrons eneters, from left to right, a uniform magnetic field (B) which is pointing upwards as shown in the figure. The field deflects the stream of electrons.

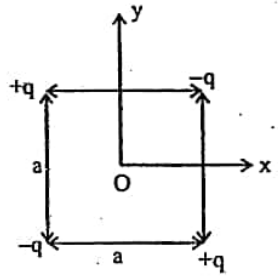


(a) Downward (in the plane of the paper)
(b) Upward (in the plane of the paper)
(c) Into the paper
(d) Out of the Paper.

56. A wire of radius R carries a current I. The magnetic induction B, inside the wire, at a distance r(<R)
(a) Is independent of R
(b) Is proportional to ln R
(c) Is proportional to r
(d) Is proportional to 1/r.

57. A charged capacitor is made of two concentric cylinders of radii r_1 and r_2. The region between the cylindrical plates is filled with a medium of dielectric constant, k. The displacement vector $(\bar{D})$ at a distance r $(r_1 < r < r_2)$.
(a) Is independent of r.
(b) Varies as ln r.
(c) Is proportional to r.
(d) Varies as 1/r.

58. The dipole moment of the following configuration about the centre:



(a) $4\,qa\left(\hat{i}+\hat{j}\right)$
(b) $2\,qa\left(\hat{i}-\hat{j}\right)$
(c) 0
(d) $8\,qa^2\,\hat{k}$

59. In which region of the electromagnetic spectrum do metals have the highest reflectivity?
(a) Infrared
(b) Visible
(c) Ultraviolet
(d) In the entire region of the spectrum

60. At the interface between two dielectric media,
(a) Normal components of $\bar{E}$ and $\bar{B}$ must be continuous.
(b) Tangential components of $\bar{E}$ and $\bar{B}$ must be continuous.
(c) Normal components of $\bar{D}$ and $\bar{H}$ must be continuous
(d) Tangential component of $\bar{E}$ and normal component of $\bar{B}$ must be continuous.

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61. The refractive indices of water and glass are $\frac{4}{3}$ and $\frac{3}{2}$ respectively. The ratio of their dielectric constants at 10^{14} Hz is:

(a) $\frac{8}{9}$ (b) $\frac{64}{81}$ (c) $\frac{81}{64}$ (d) $\frac{9}{8}$

62. A certain charge distribution consists of two equivalent dipoles which are oppositely oriented. The leading term in the expansion of the potential is that due to a

(a) Monopole (b) Dipole (c) Quadrupole (d) Octupole

63. An electron is moving with an acceleration 10 m/s² whereas a positron is moving with an acceleration 20 m/s². The ratio of the power radiated by the positron to that of electron is:

(a) 2 (b) 1/2 (c) 1/4 (d) 4

64. The magnetic field $\vec{B}$ can be expressed in terms of the vector potential as $\vec{B} = \vec{\nabla} \times \vec{A}$. If $\vec{B} = B\hat{k}$ then $\vec{A}$ can be expressed as

(a) $\left(-\frac{1}{2}By, \frac{1}{2}Bx, 0\right)$ (b) $\left(\frac{1}{2}By, -\frac{1}{2}Bx, 0\right)$ (c) $(0,0,B)$ (d) $\left(\frac{Bx}{3}, \frac{By}{3}, \frac{Bz}{3}\right)$

65. Current flowing in a circuit containing a capacitor. To satisfy the continuity equation, $\vec{\nabla}.\vec{J} = -\frac{\partial \rho}{\partial t}$, for charge and current, the current density $\vec{J}$ must be replaced by

(a) $\frac{1}{4\pi}\frac{\partial \vec{D}}{\partial t}$ (b) $\vec{J} - \frac{1}{4\pi}\frac{\partial \vec{D}}{\partial t}$ (c) $\vec{D} + \frac{1}{4\pi}\frac{\partial \vec{J}}{\partial t}$ (d) $\vec{J} + \frac{1}{4\pi}\frac{\partial \vec{D}}{\partial t}$

66. The electric field due to a charge q is given by $\vec{E} = \frac{q}{r^2}\hat{r}$. The value of the surface integral $\oint_s \vec{E}.\vec{ds}$ depends only

(a) On the area of the surface (b) On the radial distance r.
(c) On the charge (d) On the shape of the surface

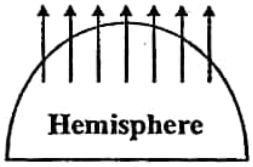
67. The relation between $\vec{H}.\vec{B}$ and $\vec{M}$ representing the magnetic intensity, magnetic field and magnetic dipole moment vectors, respectively, is

(a) $\vec{H} = -(\mu_0\vec{M} + \vec{B})$ (b) $\vec{H} = \mu_0\vec{M} - \vec{B}$
(c) $\vec{H} = \vec{B} - \mu_0\vec{M}$ (d) $\vec{H} = \vec{B} + \mu_0\vec{M}$

68. Electrical charge is stored in

(a) Battery (b) Capacitor (c) Voltmeter (d) Wire

69. What is the resultant Electric flux



(a) $2\pi R^2E$ (b) $4\pi R^2E$ (c) 0 (d) πR^2E

70. Magnetic field associated with a wire depends as

(a) $B \propto \frac{1}{r^2}$ (b) $B \propto \frac{1}{r}$ (c) $B \propto \frac{1}{r^3}$ (d) None of these

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71. For circular wire which of the following is correct

(a) $E \propto \frac{1}{r}, B \propto \frac{1}{r}$ (b) $E \propto \frac{1}{r^2}, B \propto \frac{1}{r^2}$ (c) $E \propto \frac{1}{r}, B \propto r$ (d) $E \propto \frac{1}{r^2}, B \propto \frac{1}{r}$

72. A point charge is at a distance d from a metal plate. The force acting on the charge is:
(a) Proportional to $1/d^2$ and repulsive. (b) zero
(c) Proportional to $1/d^2$ and attractive. (d) Proportional to $1/d$ and attractive.

73. One of electrostatic boundary conditions for the potential v for a surface carrying a surface charge density σ can be written as

(a) $V_{above} - V_{below} = -\frac{\sigma}{\epsilon_0}$ (b) $V_{above} - V_{below} = \frac{\sigma}{\epsilon_0}$

(c) $\frac{\partial V_{above}}{\partial n} - \frac{\partial V_{below}}{\partial n} = \frac{\sigma}{\epsilon_0}$ (d) $\frac{\partial V_{above}}{\partial n} - \frac{\partial V_{below}}{\partial n} = -\frac{\sigma}{\epsilon_0}$

74. The magnitude of the electrostatic field of an infinite straight wire carrying a line charge density λ at a distance Z from it is given by

(a) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\lambda}{Z^2}$ (b) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\lambda}{Z^2}$ (c) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\lambda}{Z}$ (d) $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\lambda}{Z}$

75. The relation $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$ where

$\vec{D} \rightarrow$ dielectric constant; $\vec{E} \rightarrow$ electric field intensity; $\vec{P} \rightarrow$ polarization vector is applicable

(a) For all medium (b) For dielectric medium
(c) Free space (d) Magnetic medium

76. For a medium of electric and magnetic field the relation between E and B with propagation vector k

(a) $\vec{E} \times \vec{k} = \omega \vec{B}$ (b) $\vec{E} \times \vec{R} = \vec{\omega} \times \vec{B}$ (c) $\vec{E} = \frac{k}{\omega} \times \vec{B}$ (d) $\vec{B} = \frac{\vec{k} \times \vec{E}}{\omega}$

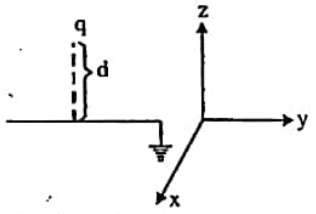
77. The condition that the magnetic field $\vec{B}$ is a curl of a vector potential $\vec{A}$ should be

(a) $\vec{\nabla} . B = 0$ (b) $\vec{\nabla} \times \vec{A} = 0$ (c) $\vec{\nabla} \vec{A} = 0$ (d) $\vec{\nabla} \times \vec{A} - \nabla^2 \vec{A} = 0$

78. A hollow, closed conductor is placed in an external electric field $\vec{E}$. Then, at equilibrium, the electric field within the cavity is:

(a) $\vec{E}$ (b) 0
(c) Can be less than $\vec{E}$ but non-zero (d) Greater than $\vec{E}$

79. Let a point charge +q be at a distance d from an infinite conducting plate which is grounded.



The force experienced by the charge is given by

(a) $\vec{F} = +\frac{1}{4\pi\varepsilon_0} \frac{q^2}{d^2} \hat{k}$ (b) $\vec{F} = -\frac{1}{4\pi\varepsilon_0} \frac{q^2}{d^2} \hat{k}$

(c) $\vec{F} = -\frac{1}{4\pi\varepsilon_0} \frac{q^2}{(2d)^2} \hat{k}$ (d) $\vec{F} = +\frac{1}{4\pi\varepsilon_0} \frac{q^2}{(2d)^2} \hat{k}$

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80. In an electrostatic boundary value problem, the surface charge density σ is specified at $x=0$. The corresponding boundary condition for potential V can be written as

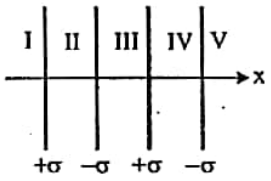
(a) $\left(\frac{\partial^2 V}{\partial x^2}\right)_{x=0} = \frac{1}{\varepsilon_0}\sigma(y,z)$ (b) $\left(\frac{\partial^2 V}{\partial x^2}\right)_{x=0} = -\frac{1}{\varepsilon_0}\sigma(y,z)$

(c) $\left(\frac{\partial V}{\partial x}\right)_{x=0} = +\frac{1}{\varepsilon_0}\sigma(y,z)$ (d) $\left(\frac{\partial V}{\partial x}\right)_{x=0} = -\frac{1}{\varepsilon_0}\sigma(y,z)$

81. Let a right circularly polarized light be incident normally on an ordinary mirro. The reflected light is:

(a) Elliptically polarized (b) Right circularly polarized
(c) Left circularly polarized (d) Linearly polarized

82. Four infinite conducting plates carry equal but opposite uniform charge densities $+\sigma$ as shown. The electrostatic fields in the regions I, II, III, IV and V are given respectively by



(a) $0, \frac{\sigma}{\varepsilon_0}\hat{x}, 0, \frac{\sigma}{\varepsilon_0}\hat{x}, 0$ (b) $\frac{\sigma}{\varepsilon_0}\hat{x}, 0, \frac{\sigma}{\varepsilon_0}\hat{x}, 0, \frac{\sigma}{\varepsilon_0}\hat{x}$

(c) $0, \frac{\sigma}{\varepsilon_0}\hat{x}, -\frac{\sigma}{\varepsilon_0}\hat{x}, \frac{\sigma}{\varepsilon_0}\hat{x}, 0$ (d) $0, +\frac{\sigma}{\varepsilon_0}\hat{x}, \frac{\sigma}{2\varepsilon_0}\hat{x}, +\frac{\sigma}{\varepsilon_0}\hat{x}, 0$

83. A charge q moves in a combined electric field $\vec{E}$ and magnetic induction $\vec{B}$. Then, as the charge moves

(a) Both the electric field and magnetic induction do work on it.
(b) The electric field does work but magnetic induction does no work on it.
(c) Magnetic induction does work but electric field does no work on it.
(d) Both electric field and magnetic induction do no work on it.

84. In charge free and current free space, the following is true:

(a) $\vec{\nabla}\times\vec{H} = \frac{\partial \vec{B}}{\partial t}$ (b) $\vec{\nabla}\times\vec{H} = 0$ (c) $\vec{\nabla}\times\vec{H} = \frac{\partial \vec{D}}{\partial t}$ (d) $\vec{\nabla}\times\vec{H} = -\frac{\partial \vec{D}}{\partial t}$

85. Let $\vec{A}$ and φ denote the vector and scalar potentials, respectively, which are Lorentz gauge invariant. $\vec{A}$ and φ satisfy.

(a) $\text{div}\vec{A} + \frac{1}{c}\frac{\partial \varphi}{\partial t} = 0$ (b) $\text{div}\vec{A} + \frac{1}{c^2}\frac{\partial \varphi}{\partial t} = 0$ (c) $\nabla^2\vec{A} + \frac{1}{c}\frac{\partial \varphi}{dt} = 0$ (d) $\nabla^2\vec{A} + \frac{1}{c}\frac{\partial A}{dt} = 0$

86. Two point charges q and 4q are located at r_1 and r_2, respectively, on the xy-plane. The magnitude Q and location R of a third charge to be placed on the plane such that total force on the each of the three charges vanishes, are

(a) $Q = -4q/9$ and $R = (2r_1 + r_2)/3$ (b) $Q = -4q/5$ and $R = (r_1 + 2r_2)/3$

(c) $Q = -4q/25$ and $R = (16r_1 + r_2)/\sqrt{17}$ (d) $Q = -9q/4$ and $R = (r_1 + 2r_2)/3$

87. Consider a spherical cavity in an infinite, homogeneous and isotropic dielectric material of permittivity ε. When placed in an external electric field E, the electric field inside the cavity is:

(a) $3\varepsilon E/(2\varepsilon + \varepsilon_0)$ (b) $(2\varepsilon + \varepsilon_0)E/3\varepsilon$ (c) $-\varepsilon E$ (d) E/ε

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88. A circular coil of radius 120 mm with 10 turns is placed with its plane parallel to the earth's magnetic field. When a current of 0.45 A flows through the coil, a compass needle placed at the center of the coil is seen to be deflected by an angle of 45° to the plane of the coil. The intensity of the earth's magnetic field is calculated to be
(a) 0.3 μT (b) 24 μT (c) 42 μT (d) 100 μT

89. Electric current of uniform current density is flowing through an infinitely long wire with a circular cross-section of constant radius R. Which of the following relations gives the magnitude B of the magnetic field measured inside the wire at a distance r from the central axis of the wire (so that $r < R$)?
(a) $B \propto r$ (b) $B \propto \ln r$ (c) $B \propto 1/r$ (d) $B \propto 1/r^2$

90. The amount of energy required to charge a metallic sphere of radius 2.0 m to a potential of 3000 V in air is:
(a) 1×10^{-3} Joule (b) 2×10^{-3} Joule (c) 3×10^{-3} Joule (d) 4×10^{-3} Joule

91. In a region of space that does not contain any electric charge, the electrostatic potential satisfies Laplace's equation. Suppose that the potential in such a situation is given by the formula

$$V(x,y,z) = A\left(bx^2 + \frac{1}{2}y^2 - z^2\right)$$

Where A and b are constants. Then the value of b
(a) Can be arbitrary (b) Must be zero (c) Must be 1/2 (d) Must be 1

92. Suppose that the electric field on the xy-plane is given by

$$\vec{E} = P\left[xy\hat{i} + \left(\frac{1}{2}x^2 + y^2\right)\hat{j}\right]$$

$V = -\int_a^b \vec{E}\cdot d\vec{l}$

The magnitude of the difference in potential between the origin (0, 0) and the point (1, 2) is:
(a) $\frac{5}{4}P$ (b) $\frac{11}{3}P$ (c) $\frac{7}{2}P$
(d) Not unique, it depends on the path joining the two points.

93. Four electric charges of strength Q, Q, –Q and –Q are placed respectively at the points (–b, 0), (b, 0), (0, –a) and (0, a) on the xy plane. At a distance d very far away from these charges ($d >> a, b$), the electric field will appear to be approximately that of
(a) A point charge (b) A dipole
(c) A quadrupole (d) A mixture of a dipole and a quadrupole

94. The potential due to an electric dipole P placed at the origin is known to be of the form $\phi(r) = P.r/r^3$. The total flux of the electric field through a spherical surface of radius R with the dipole at the centre is given by
(a) Zero (b) $-\frac{2\pi}{3}\frac{|p|}{R}$ (c) $+\frac{2\pi}{3}\frac{|p|}{R}$ (d) $+\frac{4\pi}{3}\frac{|p|}{R}$

$V_{DIP}(r,\theta) = \frac{P.\hat{r}}{4\pi\epsilon_0 r^2} = \frac{P\cos\theta}{4\pi\epsilon_0 r^2}$

$\phi_E = \int_S \vec{E}\cdot d\vec{a}$

$\vec{E} = -\nabla V$

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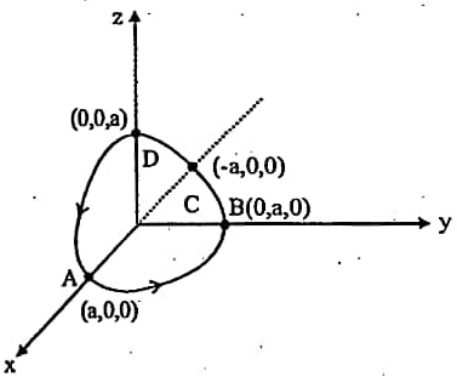
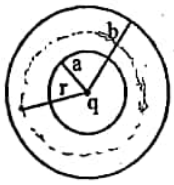
95. In the following figure, ABC and CDA are two semicircular conducting wires of radius a with the origin as their common centre. The arc ABC lies on the xy-plane whereas CDA lies on the xz-plane. They are joined as shown. This combined loop carries a current in the direction indicated in the figure below. Which of the following unit vectors denotes the direction of the resulting magnetic field vector at the origin?



(a) $(1,0,0)$ (b) $\left(0,\frac{1}{\sqrt{2}},\frac{1}{\sqrt{2}}\right)$ (c) $\left(\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}\right)$ (d) $(-1,0,0)$

96. A conducting spherical shell of inner radius a and outer radius b has a point charge q located at the centre of the shell. The potential at a distance r from the centre ($a < r < b$) is:



(a) 0 (b) $\frac{1}{4\pi\varepsilon_0}\frac{q}{a}$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{b}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

97. Consider the electric and magnetic fields of an accelerating charge. How should the fields vary with r (the retarded distance) for the poynting vector to remain finite at arbitrary large distances?

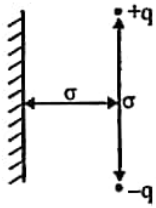
(a) $1/r$ (b) $1/r^2$ (c) r d) r^2

98. According to Kirchoff's laws for the circuits, the sum of the currents at any junction is equal to zero. Which of the following equations for the current density $\vec{j}$ describes this situation?

(a) $\vec{\nabla}\times\vec{j}=0$ (b) $\vec{\nabla}.\vec{j}=0$

(c) $\nabla^2\vec{j}=0$ (d) $\partial\vec{j}/\partial t=0$

99. Two equal and opposite charges are placed at a distance r from each other. A large metallic sheet is placed at a distance d from them as shown in figure. Due to presence of the sheet, the attractive force between the charges along the direction joining them



(a) decreases (b) Increases

(c) Remains unchanged. (d) Decreases if $r > d/2$ and increases if $r < d/2$.

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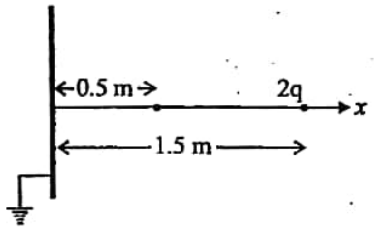
100. Two charges q and 2q are placed along the x-axis in front of a grounded, infinite conducting plane, as shown in the figure. They are located respectively at a distance of 0.5 m and 1.5 m from the plane. The force acting on the charge q is:



(a) $\frac{1}{4\pi\varepsilon_0}\frac{7q^2}{2}$ (b) $\frac{1}{4\pi\varepsilon_0}2q^2$ (c) $\frac{1}{4\pi\varepsilon_0}q^2$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{2}$

101. A uniform surface current is flowing in the positive y-direction over an infinite sheet lying in x-y plane. The direction of the magnetic field is:

(a) Along $\hat{i}$ for $z>0$ and along $-\hat{i}$ for $z<0$. (b) Along $\hat{k}$ for $z>0$ and along $-\hat{k}$ for $z<0$

(c) Along $-\hat{i}$ for $z>0$ and along $\hat{i}$ for $z<0$ (d) Along $-\hat{k}$ for $z>0$ and along $\hat{k}$ for $z<0$

102. A magnetic dipole of dipole moment $\vec{m}$ is placed in a non-uniform field $\vec{B}$. If the position vector of the dipole is $\vec{r}$, the torque acting on the dipole about the origin is:

(a) $\vec{r}\times(\vec{m}\times\vec{B})$ (b) $\vec{r}\times\vec{\nabla}(\vec{m}.\vec{B})$ (c) $\vec{m}\times\vec{B}$ (d) $\vec{m}\times\vec{B}+\vec{r}\times\vec{\nabla}(\vec{m}.\vec{B})$

103. Which of the following expressions for a vector potential $\vec{A}$ **DOES NOT** represent a uniform magnetic field of magnitude B_0 along the z-direction?

(a) $\vec{A}=(0,B_0x,0)$ (b) $\vec{A}=(-B_0y,0,0)$ (c) $\vec{A}=\left(\frac{B_0x}{2},\frac{B_0y}{2},0\right)$ (d) $\vec{A}=\left(-\frac{B_0y}{2},\frac{B_0x}{2},0\right)$

104. A conducting sheet has infinite dimensions in the Y and Z directions and semi-infinite in the X direction. The Z component of the current density $\vec{J}$ is :

(a) Exponentially increasing (b) Exponentially decreasing
(c) Constant (d) Oscillating.

105. The ratio of cyclotron frequencies of an α-particle and a proton moving in the same magnetic field $\vec{B}$ is:

(a) 1/2 (b) 2 (c) 4 (d) 1/4

106. The vector potential of a moving charge is dependent upon

(a) Its velocity only (b) Its charge only (c) Its momentum (d) Its velocity and charge

107 In vacuum the electric field of individual particles are $\vec{E}_1$ and $\vec{E}_2$ then $\vec{E}=\vec{E}_1+\vec{E}_2$ the total energy will be

(a) The sum of individual energy (b) The sum of the square of individual energy.
(c) The square of the sum of individual energy (d) None of these.

108. For constant uniform electric and magnetic fields $\vec{E}=\vec{E}_0$ and $\vec{B}=\vec{B}_0$, it is possible to choose a gauge such that the scalar potential ϕ and vector potential $\vec{A}$ are given by

(a) $\phi=0$ and $\vec{A}=\frac{1}{2}(\vec{B}_0\times\vec{r})$ (b) $\phi=-\vec{E}_0.\vec{r}$ and $\vec{A}=\frac{1}{2}(\vec{B}_0\times\vec{r})$

(c) $\phi=-\vec{E}_0.\vec{r}$ and $\vec{A}=0$ (d) $\phi=0$ and $\vec{A}=-\vec{E}_0t$

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109. The electrostatic potential V(x,y) in free space in a region where the charge density ρ is zero is given by $V(x,y) = 4e^{2x} + f(x) - 3y^2$. Given that the x-component of the electric field, E_x, and V are zero at the origin, f(x) is:

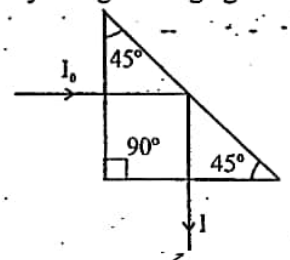
(a) $3x^2 - 4e^{2x} + 8x$ (b) $3x^2 - 4e^{2x} + 16x$ (c) $4e^{2x} - 8$ (d) $3x^2 - 4e^{2x}$

110. A plane electromagnetic wave is propagating in a lossless dielectric. The electric field is given by $E(x,y,z,t) = E_0(\hat{x} + A\hat{z})\exp\left[ik_0\left\{-ct + \left(x + \sqrt{3}z\right)\right\}\right]$, where c is the speed of light in vacuum, E_0, A and k_0 are constants and $\hat{x}$ and $\hat{z}$ are unit vectors along the x- and z-axes. The relative dielectric constant of the medium, ε_r and the constant A are

(a) $\varepsilon_r = 4$ and $A = -\frac{1}{\sqrt{3}}$ (b) $\varepsilon_r = 4$ and $A = +\frac{1}{\sqrt{3}}$

(c) $\varepsilon_r = 4$ and $A = \sqrt{3}$ (d) $\varepsilon_r = 4$ and $A = -\sqrt{3}$

111. Circularly polarized light with intensity I_0 is incident normally on a glass prism as shown in the figure. The index of refraction of glass is 1.5. The intensity I of light emerging from the prism is:



(a) I_0 (b) $0.96\,I_0$ (c) $0.92\,I_0$ (d) $0.88\,I_0$

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Assignment-II: Electromagnetic Theory

1. A wire of circular cross section of radius R carries a volume current density $\vec{J} = kr^2\hat{z}$ along the length of the wire. The magnetic field at a position r < R is :

(a) $\frac{\mu_0}{2} k r^3 \hat{z}$ (b) $\frac{\mu_0}{4} k r^3 \hat{\phi}$ (c) $\frac{\mu_0}{4\pi} k r^3 \hat{r}$ (d) $\frac{\mu_0}{4\pi} k r^2 \hat{\phi}$

2. Three infinitely long parallel wires separated by a distance d from each other, carrying current I each are kept in the same plane. The magnetic field is found to be zero at a distance x on both sides of the central wire. The values of x are :

(a) $\pm d/2$ (b) $\pm d/\sqrt{2}$ (c) $\pm d/\sqrt{3}$ (d) $\pm d/3$

3. Consider an infinite plane at z = 0 with uniform surface current density $\vec{K} = K\hat{i}$. The direction of the magnetic field $\vec{B}$ and the vector potential $\vec{A}$ of this current distribution at a distance d along the positive z-axis are :

(a) $\vec{B}$ along $\hat{j}$ and $\vec{A}$ along $\hat{k}$ (b) $\vec{B}$ along $\hat{k}$ and $\vec{A}$ along $\hat{j}$

(c) $\vec{B}$ along $-\hat{j}$ and $\vec{A}$ along $\hat{i}$ (d) $\vec{B}$ along $\hat{i}$ and $\vec{A}$ along $-\hat{j}$

4. The electric field of two linearly polarized waves are given by $\vec{E}_1 = \hat{i}E_x \cos(\omega t - \theta_1)$ and $\vec{E}_2 = \hat{j}E_y \cos(\omega t - \theta_2)$. The nature of polarization of the superimposed wave is :

(a) Unpolarized (b) Linearly polarized

(c) Circularly polarized (d) Elliptically polarized (in general type of polarization)

5. In a free space, which is the correct set of Maxwell's equations in absence of any charges and current densities :

(a) $\vec{\nabla}.\vec{E} = \rho/\varepsilon_0, \vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$
$\vec{\nabla}.\vec{B} = 0, \vec{\nabla}\times\vec{B} = \mu_0\varepsilon_0\frac{\partial \vec{E}}{\partial t}$

(b) $\vec{\nabla}.\vec{E} = 0, \vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$
$\vec{\nabla}.\vec{B} = 0, \vec{\nabla}\times\vec{B} = \mu_0\vec{J}$

(c) $\vec{\nabla}.\vec{E} = \rho/\varepsilon_0, \vec{\nabla}\times\vec{E} = 0$ (d)
$\vec{\nabla}.\vec{B} = 0, \vec{\nabla}\times\vec{B} = \mu_0\varepsilon_0\frac{\partial \vec{E}}{\partial t}$

(d) $\vec{\nabla}.\vec{E} = 0, \vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$
$\vec{\nabla}.\vec{B} = 0. \vec{\nabla}\times\vec{B} = \mu_0\varepsilon_0\frac{\partial \vec{E}}{\partial t}$

6. A conducting loop L of surface area S is moving with a velocity $\vec{v}$ in a magnetic field $\vec{B}(\vec{r}, t) = \vec{B}_0 t^2$, B_0 is a positive constant of suitable dimensions. The emf induced, V_{emf}, in the loop is given by :

(a) $-\int_S \frac{\partial \vec{B}}{\partial t}.d\vec{S}$ (b) $\oint_L (\vec{v}\times\vec{B}).d\vec{L}$

(c) $-\int_S \frac{\partial \vec{B}}{dt}.d\vec{S} - \oint_L (\vec{v}\times\vec{B}).d\vec{L}$ (d) $-\int_S \frac{\partial \vec{B}}{dt}.d\vec{S} + \oint_L (\vec{v}\times\vec{B}).d\vec{L}$

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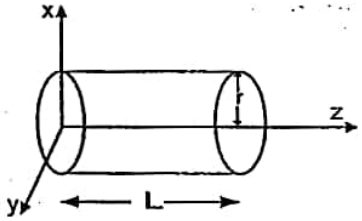
7. A cylindrical rod of length L and radius r, made of an inhomogeneous dielectric, is placed with its axis along the z direction with one end at the origin as shown below :



If the rod carries a polarization, $\vec{P} = (5z^2 + 7)\hat{k}$, the volume bound charge inside the dielectric is :

(a) Zero (b) $10\pi r^2 L$ (c) $-5\pi r^2 L$ (d) $-5\pi r^2 L^2$

8. A long cylindrical kept along z-axis carries a current density $\hat{J} = J_0 r\hat{k}$, where J_0 is a constant and r is the radial distance form the axis of the cylinder. The magnetic induction $\hat{B}$ inside the conductor at a distance d from the axis of the cylinder is :

(a) $\mu_0 J_0 \hat{\phi}$ (b) $\frac{\mu_0 J_0 d}{2}\hat{\phi}$ (c) $\frac{\mu_0 J_0 d^2}{3}\hat{\phi}$ (d) $\frac{\mu_0 J_0 d^3}{4}\hat{\phi}$

9. A particle is moving in an inverse square force field. If the total energy of the particle is positive, then trajectory of the particle is :

(a) Circular (b) Elliptical (c) Parabolic (d) Hyperbolic

Statement for linked Answer Q.10 and Q.11:

An infinitely long hollow cylinder of radius R carrying a surface charge density σ is rotated about its cylinderical axis with a constant angular speed ω

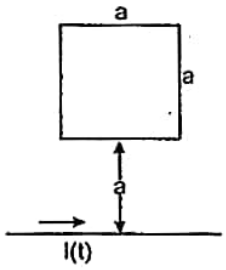
10. The magnitude of the surface current is :

(a) $\sigma R\omega$ (b) $2\sigma R\omega$ (c) $\pi\sigma R\omega$ (d) $2\pi\sigma R\omega$

11. The magnitude of vector potential inside the cylinder at a distance from its axis is :

(a) $2\mu_0\sigma R\omega r$ (b) $\mu_0\sigma R\omega r$ (c) $\frac{1}{2}\mu_0\sigma R\omega r$ (d) $\frac{1}{4}\mu_0\sigma R\omega r$

12. An infinitely long wire carrying a current $I(t) = I_0 \cos(\omega t)$ is placed at a distance a from a square loop of side a as shown in the figure. If the resistance of the loop is R, then the amplitude of the induced current in the loop is :



(a) $\frac{\mu_0}{2\pi}\frac{aI_0\omega}{R}\ln 2$ (b) $\frac{\mu_0}{\pi}\frac{aI_0\omega}{R}\ln 2$

(c) $\frac{2\mu_0}{\pi}\frac{aI_0\omega}{R}\ln 2$ (d) $\frac{\mu_0}{2\pi}\frac{aI_0\omega}{R}$

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13. A plane electromagnetic wave travelling in vaccum is incident normally on a non magnetic, non-absorbing medium of refractive index n. The incident (E_i), reflected (E_r) and transmitted (E_t) electric fields are given as,

$$E_i = E\exp\left[i(kz-\omega t)\right], E_r = E_{or}\exp\left[i(k_r z-\omega t)\right], E_t = E_{0t}\exp\left[i(k_t z-\omega t)\right]$$

If E = 2 V/m and n = 1.5 then the application of appropriate boundary conditions leads to :

(a) $E_{0r} = -\frac{3}{5}V/m, E_{0t} = \frac{7}{5}V/m$ (b) $E_{0r} = -\frac{1}{5}V/m, E_{0t} = \frac{8}{5}V/m$

(c) $E_{0r} = -\frac{2}{5}V/m, E_{0t} = \frac{8}{5}V/m$ (d) $E_{0r} = \frac{4}{5}V/m, E_{0t} = \frac{6}{5}V/m$

14. Consider the following three independent cases :
(i) Particle A of charge +q moves in free space with a constant velocity $\vec{\upsilon}(\upsilon << \text{speed of light})$
(ii) Particle B of charge +q moves in free space in a circle of radius R with same speed υ as in case (i)
(iii) Particle C having charge –q moves as in case (ii)
If the powers radiated by A, B and C are P_A, P_B and P_C respectively, then :

(a) $P_A = 0, P_B > P_C$ (b) $P_A = 0, P_B = P_C$

(c) $P_A > P_B > P_C$ (d) $P_A = P_B = P_C$

15. The electric (E) and magnetic (B) field amplitudes associated with an electromagnetic radiation from a point source behave at a distance r from the source as :

(a) E = constant, B = constant (b) $E \propto \frac{1}{r}, B \propto \frac{1}{r}$

(c) $E \propto \frac{1}{r^2}, B \propto \frac{1}{r^2}$ (d) $E \propto \frac{1}{r^3}, B \propto \frac{1}{r^3}$

16. The electric field $\vec{E}(\vec{r},t)$ for a circularly polarized electromagnetic wave propagating along the positive z direction is :

(a) $E_0(\hat{x}+\hat{y})\exp\left[i(kz-\omega t)\right]$ (b) $E_0(\hat{x}+i\hat{y})\exp\left[i(kz-\omega t)\right]$

(c) $E_0(\hat{x}+i\hat{y})\exp\left[i(kz+\omega t)\right]$ (d) $E_0(\hat{x}+\hat{y})\exp\left[i(kz+\omega t)\right]$

17. Three infinitely long wires are placed equally apart on the circumference of a circle of radius a, perpendicular to its plane. Two of the wires carry current I each, in the same direction, while the third carries current 2I along the direction opposite to the other two. The magnitude of the magnetic induction $\vec{B}$ at a distance r from the centre of the circle, for r > a, is :

(a) 0 (b) $\frac{2\mu_0}{\pi}\frac{I}{r}$ (c) $-\frac{2\mu_0}{\pi}\frac{I}{r}$ (d) $\frac{2\mu_0}{\pi}\frac{Ia}{r^2}$

18. Which one of the following statements is TRUE?
(a) The magnitude of the electric field is attenuated as the wave propagates
(b) The energy of the e.m. wave flows along the x-direction
(c) The magnitude of the electric field of the wave is a constant
(d) The speed of the wave is the same as c(speed of light in free space)

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19. The magnetic field $\vec{B}$ of the wave is :

(a) $\hat{y}\frac{k}{\omega}E_0 \exp(-zk\sin\phi)\exp[i(zk\cos\phi-\omega t)]$

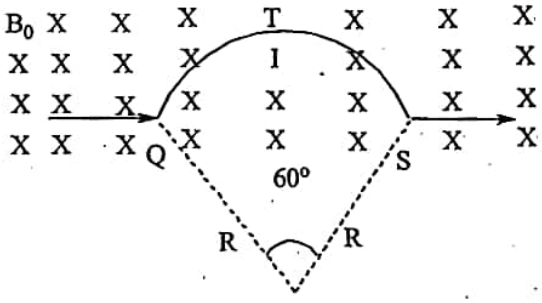
(b) $\hat{y}\frac{k}{\omega}E_0 \exp(-zk\sin\phi)\exp[i(zk\cos\phi-\omega t+\phi)]$

(c) $\hat{y}\frac{k}{\omega}E_0 \exp[i(zk\cos\phi-\omega t+\phi)]$

(d) $\hat{y}\frac{k}{\omega}E_0 \exp(-zk\cos\phi)\exp[i(zk\sin\phi-\omega t)]$

20. Which one of the following statements is TRUE?
(a) The magnitude of the electric field is attenuated as the wave propagates
(b) The energy of the e.m. wave flows along the x-direction
(c) The magnitude of the electric field of the wave is a constant
(d) The speed of the wave is the same as c(speed of light in free space)

21. A circular arc QTS is kept in an external magnetic field $\vec{B}_0$ as shown in figure. The arc carries a current I. The magnetic field is directed normal and into the page. The force acting on the arc is :



(a) $2IB_0\hat{k}R$ (b) $IB_0R\hat{k}$ (c) $-2IB_0R\hat{k}$ (d) $-IB_0R\hat{k}$

22. A conducting sphere of radius R is placed in a uniform electric field $\vec{E}_0$ directed along + z axis. The electric potential for outside points is given as :

$V_{out} = -E_0\left(1-\frac{R^3}{r^3}\right)r\cos\theta$, where r is the distance from the centrer and θ is the polar angle. The charge density on the surfae of the sphere is :

(a) $3\varepsilon_0E_0\cos\theta$ (b) $\varepsilon_0E_0\cos\theta$ (c) $3\varepsilon_0E_0\cos\theta$ (d) $\frac{\varepsilon_0}{3}E_0\cos\theta$

23. The state of polarization of light with the electric field vector
$\vec{E} = \hat{i}E_0\cos(kz-\omega t) - \hat{j}E_0\cos(kz-\omega t)$ is :
(a) Linearly polarized along z-direction
(b) Linearly polarized at –45° to x-axis
(c) Circularly polarized
(d) Elliptically polarized with the major axis along x- axis

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Data for Q. 24 and Q.25.

Consider two conducting plates of infinite extent, one plate at z = 0 and the other at z = L, both parallel to the xy plane. The vector and scalar potential in the region between the plates is given by:

$A(r,t) = A_0\, i \cos(kz+\alpha)\cos(kct);\ \phi(r,t) = 0$

24. For this to represent a standing wave in the empty region between the plates :

(a) $k = \pi/L$ and $\alpha = 0$ (b) $k = 2\pi/L$ and $\alpha = \pi/2$

(c) $k = \pi/(2L)$ and $\alpha = \pi/2$ (d) $k = \pi/2L$ and $\alpha = 0$

25. The energy density at z = 0 and t = 0 is :

(a) 0 (b) $\varepsilon_0 c^2 k^2 A_0^2$

(c) $(1/2)\mu_0 A_0^2 k^2$ (d) $(1/2)\mu_0 A_0^2 k^2 + (1/2)\varepsilon_0 c^2 k^2 A_0^2$

26. Consider the given statements about E(r, t) and B(r, t), the electric and magnetic vectors respectively in a region of free space

P. Both E and B are conservative vector fields

Q. Both E and B are central force fields

R. E and B are mutually perpendicular in the region

S. Work done by B on a moving charge in the region is zero

Choose the right combination of correct statements from the following :

(a) P and R (b) R and S (c) S only (d) P and Q

27. Electromagnetic waves are propagating along a hollow, metallic waveguide whose cross-section is a square of side W. The minimum frequency of the electromagnetic waves is :

(a) c/W (b) 2c/W (c) $\pi c/W$ (d) $\sqrt{2}\,\pi c/W$

28. An electric field applied along the length of a long cylinder produces a polarization P. The depolarization field produced in this configuration is :

(a) $4\pi P/3$ (b) $-4\pi P/3$ (c) $2\pi P$ (d) 0

29. An electric charge, +Q is placed on the surface of a solid, conduction sphere of radius a. The distance measured from the centre of the sphere is denoted as r. Then :

(a) The charge gets distributed uniformly through the volume of the sphere

(b) The electrostatic potential has the same value for r < a

(c) An equal and opposite charge gets induced in the bottom half of the sphere

(d) The electric field is given by $1/(4\pi\varepsilon_0 r^2)$ for r < a

30. A large circular coil of N turns and radius R carries a time varying current $i = i_0 \sin(\omega t)$. A small circular coil of n turns and radius r (r <<R) is placed at the center of the large coil such that the coils are concentric and coplanar. The induced emf in the small coil

(a) Leads the current in the large coil by $\pi/2$

(b) Lags the current in the large coil by π

(c) Is in phase with the current in the large coil

(d) lags the current in the large coil by $\pi/2$

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31. The electric field E(r, t) at a point r at time t in a metal due to the passage of electrons can be described by the equation

$$\nabla^2\vec{E}(\vec{r},t)=\frac{1}{c^2}\left[\frac{\partial^2\vec{E}(\vec{r},t)}{\partial t^2}+\omega'^2\vec{E}(\vec{r},t)\right]$$

Where ω' is a characteristic associated with the metal and c is the speed of light in vacuum. The dispersion relation corresponding to the plane wave solutions of the form $\exp\left[i\left(\vec{k}.\vec{r}-\omega t\right)\right]$ is given by :

(a) $\omega^2=c^2k^2-\omega'^2$ (b) $\omega^2=c^2k^2+\omega'^2$ (c) $\omega^2=ck-\omega'$ (d) $\omega=ck+\omega'$

32. The x and y plane carries a uniform surface current of density $\vec{K}=50\,\hat{e}_z\ A/m$. The magnetic field at the point z = –0.5 m is :

(a) 10×10^{-6} Wb (b) 1×10^{-6} Wb (c) $\pi\times10^{-6}$ Wb (d) $10\pi\times10^{-6}$ Wb

33. A coaxial cable of uniform cross-section contains an insulating material of dielectric constant 3.5. The radius of the central wire is 0.01 m and that of the sheath is 0.02 m. The capacitance per kilometer of a cable is :

(a) 280.5 nF (b) 28.05 nF (c) 56.10nF (d) 2.805 nF

34. A thin conducting wire is bent into a circular loop of radius r and placed in a time dependent magnetic field of magnetic induction.

$\vec{B}(r)=B_0e^{-\alpha t}\hat{e}_z,(B_0>0\text{ and }\alpha>0)$,

such that, the plane of the loop is perpendicular to $\vec{B}(t)$. Then the induced emf in the loop is :

(a) $\pi r^2\alpha B_0\,e^{-\alpha t}$ (b) $\pi r^2B_0\,e^{-\alpha t}$ (c) $-\pi r^2\alpha B_0\,e^{-\alpha t}$ (d) $-\pi r^2\,B_0\,e^{-\alpha t}$

35. A current I flows in the anticlockwise direction through a square loop of side a lying in the xoy plane with its center at the origin. The magnetic induction at the center of the square loop is :

(a) $\frac{2\sqrt{2}\mu_0 I}{\pi a}\hat{e}_x$ (b) $\frac{2\sqrt{2}\mu_0 I}{\pi a}\hat{e}_z$ (c) $\frac{2\sqrt{2}\mu_0 I}{\pi a^2}\hat{e}_z$ (d) $\frac{2\sqrt{2}\mu_0 I}{\pi a^2}\hat{e}_x$

36. Which of the following equations is relativistically invariant ? (α, β, γ and δ are constants of suitable dimensions).

(a) $\frac{\partial\phi(x,t)}{\partial t}=\alpha\frac{\partial^2\phi(x,t)}{dx^2}$ (b) $\frac{\partial^2\phi(x,t)}{\partial t^2}=\beta\frac{\partial^2\phi(x,t)}{\partial x^2}$

(c) $\frac{\partial^2\phi(x,t)}{\partial t^2}=\gamma\frac{\partial\phi(x,t)}{\partial x}$ (d) $\frac{\partial^2\phi(x,t)}{\partial t}=\delta\frac{\partial^3\phi(x,t)}{\partial x^3}$

37. Three plane waves are given as $\bar{y}_1=A_1\,\hat{y}.\cos(kx-\omega t+\delta_1)$, $\bar{y}_2=A_2\,\hat{z}\cos(kx-\omega t+\delta_2)$

$\bar{y}_3=A_3\,\hat{y}\cos(kx-\omega t+\delta_3)$, where $\delta_1,\delta_2,\delta_3$ and A_1,A_2,A_3 are constants. If these waves are superposed pairwise, which superposition will lead to interference?

(a) $\bar{y}_1$ and $\bar{y}_2$ (b) $\bar{y}_2$ and $\bar{y}_3$

(c) $\bar{y}_1$ and $\bar{y}_3$ (d) No interference in any pair

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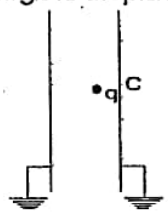
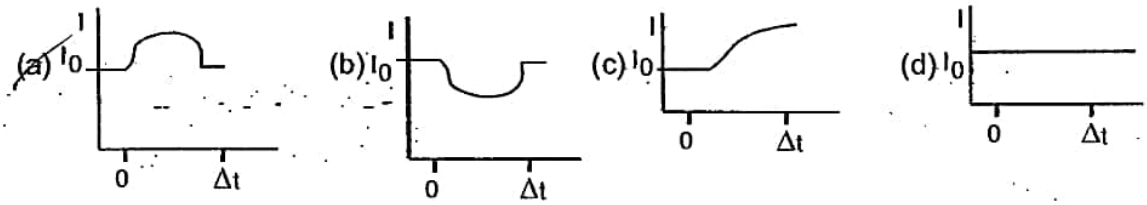
38. A point charge q is kept at the mid-point between two large parallel grounded conducting plates. Assume no gravity. The charge is displaced a little towards the right plate. The charge will now,

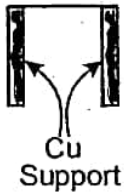


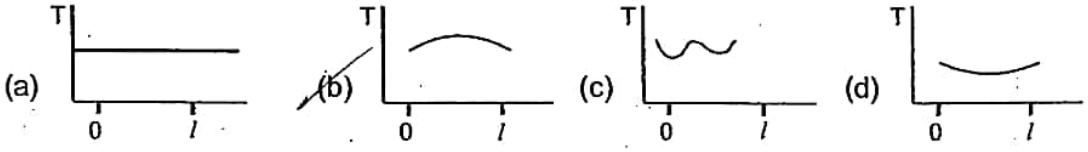
(a) Stay where it is
(b) Move towards the right plate
(c) Move towards the left plate
(d) Oscillate between the plates

39. A solenoid with an iron core is connected in series with a battery of emf V and it is found that a constant current I_0 passes through the solenoid. If at t = 0, the iron core is pulled out from the solenoid quickly in a time Δt, which one of the following could be a correct description of the current passing through the solenoid?

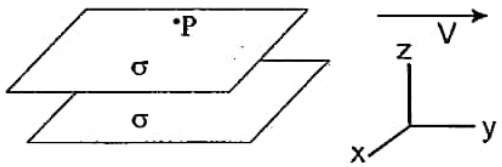


40. A tungsten wire of uniform cross section and high resistance is supported by two copper supports of low resistance in vacuum. The length of the wire is *l*. A constant current I is sent through the wire. The temperature profile (Tvs. x) of the wire will look like.





41. Two large parallel plates move with a constant speed v in the positive y-direction as shown in the figure. If both the plates have a surface charge density $\sigma > 0$, the magnetic field at the point P just above the top plate will have :



$\beta = 0$
$B = 0$

(a) Larger magnitude than the field at the mid-point between the plates and point towards $-\hat{x}$
(b) Smaller magnitude than the field at the mid-point between the plates and point towards $+\hat{x}$.
(c) Larger magnitude than the field at the mid-point between the plates and point towards $+\hat{x}$
(d) Smaller magnitude than the field at the mid-point between the plates and point towards $-\hat{x}$

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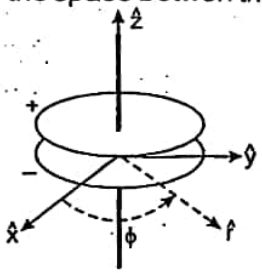
42. A parallel plate capacitor is being discharged. What is the direction of the energy flow in terms of the poynting vector in the space betwen the plates?



(a) Along the wire in the positive z axis (b) Radially inward $(-\hat{r})$

(c) Radially outward $(\hat{r})$ (d) Circumferential (ϕ)

43. Unpolarized light falls from air to a planar air-glass interface (refractive index of glass is 1.5) and the reflected light is observed to be plane polarized. The polarization vector and the angle of incidence θ_i are :

(a) Perpendicular to the plane of incidence and $\theta_i = 42°$

(b) Parallel to the plane of incidence and $\theta_i = 56°$

(c) Perpendicular to the plane of incidence and $\theta_i = 56°$

(d) Parallel to the plane of incidence and $\theta_i = 42°$

44. A finite wave train, of an unspecified nature, propagates along the positive x axis with a constant speed v and without any change of shape. The differential equation among the four listed below, whose solution it must be, is :

(a) $\left(\frac{\partial^2}{\partial x^2} - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right)\psi(x,t) = 0$ (b) $\left(\nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right)\psi(\bar{r},t) = 0$

(c) $\left(-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial t^2} - i\hbar\frac{\partial}{\partial t}\right)\psi(x,t) = 0$ (d) $\left(\nabla^2 + a\frac{\partial}{\partial t}\right)\psi(\bar{r},t) = 0$

45. A plane electromagnetic wave is given by $E_0\left(\hat{x} + e^{i\delta}\hat{y}\right)\exp\{i(kz - \omega t)\}$. At a given location, the number of times $\bar{E}$ vanishes in one second is :

(a) An integer near $\frac{\omega}{\pi}$ when $\delta = n\pi$ and zero when $\delta \neq n\pi$, n is integer

(b) An integer near $\frac{\omega}{\pi}$ and is independent of δ

(d) An integer near $\frac{\omega}{2\pi}$ when $\delta = n\pi$ and zero when $\delta \neq n\pi$, n is integer

(d) An integer near $\frac{\omega}{2\pi}$ and is independent of δ

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46. Consider an infinite horizontal surface with fixed surface charge density σ, where $\hat{n}$ is the upward normal to the surface. If an electric field $\vec{E}_b = E\hat{n}$ is applied from below, the electric field $\vec{E}_a$ in the region above the surface is:

(a) $\vec{E}_a = \vec{E}_b - \frac{\sigma}{2\varepsilon_0}\hat{n}$ (b) $\vec{E}_a = \vec{E}_b + \frac{\sigma}{2\varepsilon_0}\hat{n}$

(c) $\vec{E}_a = \vec{E}_b - \frac{\sigma}{\varepsilon_0}\hat{n}$ (d) $\vec{E}_a = \vec{E}_b + \frac{\sigma}{\varepsilon_0}\hat{n}$

47. A charged particle is travelling in the positive x-direction with a constant velocity. An observer located at a point P on the y-axis observes the electric field due to this charge. Let $\hat{e}(t)$ be the unit vector along the electric field at any time t, and $\hat{n}(t)$ the unit vector in the direction of the position vector of the charge with respect to the observer. Then

(a) $\hat{e}(t)$ lags behind $\hat{n}(t)$

(b) $\hat{e}(t)$ leads $\hat{n}(t)$

(c) $\hat{e}(t)$ is always in the same direction as $\hat{n}(t)$

(d) $\hat{e}(t)$ is always perpendicular to $\hat{n}(t)$

48. A current carrying loop lying in the plane of the paper is in the shape of an equilateral triangle of side a. It carries a current I in the clockwise sense. If $\hat{k}$ denotes the outward normal to the plane of the paper, the magnetic moment $\vec{m}$ due to the current loop is:

(a) $\vec{m} = a^2 I\,\hat{k}$ (b) $\vec{m} = -\frac{1}{2}a^2 I\,\hat{k}$ (c) $\vec{m} = \frac{\sqrt{3}}{2}a^2 I\,\hat{k}$ (d) $\vec{m} = -\frac{\sqrt{3}}{2}a^2 I\,\hat{k}$

49. An electric point charge +q is placed at the point (1, 1) of the xy-plane in which two grounded semi-infinite conducting plates along the positive x and y-axes meet see figure). The electric potential in the positive quadrant at a large distance r goes as

(a) $V(r) \sim r^{-1}$ (b) $V(r) \sim r^{-2}$ (c) $V(r) \sim r^{-3}$ (d) $V(r) \sim r^{-4}$

50. In a given frame of refrence, it is found that the electric field $\vec{E}(\vec{r},t)$ and the magnetic field $\vec{B}(\vec{r},t)$ are perpendicular to each other at all points, i.e., $\vec{E}(\vec{r},t).\vec{B}(\vec{r},t) = 0$. If the fields observed in any other inertial frame are $\vec{E}'$ and $\vec{B}'$, then

(a) $\vec{E}' // \vec{B}'$ at all points (b) $\vec{E}'.\vec{B}' < 0$ at all points

(c) $\vec{E}'.\vec{B}' > 0$ (d) $\vec{E}'.\vec{B}' = 0$

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51. Given any arbitrary electric and magnetic field $\vec{E}(\vec{r},t)$ and $\vec{E}(\vec{r},t)$, it is always possible to choose the scalar potential $\phi(\vec{r},t)$ and vector potential $\vec{A}(\vec{r},t)$ such that

(a) $\vec{A}(\vec{r},t)$ is identically zero.

(b) $\phi(\vec{r},t)$ is identically zero.

(c) $|\vec{A}(\vec{r},t)|$ is any given non-zero constant.

(d) The conditions $\nabla.\vec{A}=0$ and $\frac{1}{c}\frac{\partial\phi}{\partial t}+\nabla.\vec{A}=0$ are simultaneously satisfied.

52. In a certain region R, Maxwell's equations for the electric and magnetic fields are given by

$$\nabla.\vec{E}=0, \nabla.\vec{B}=0, \nabla\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}, \nabla\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$$

We may conclude that

(a) Both the scalar and the vector potential are necessarily constant in the region R.

(b) The electric field $\vec{E}$ and the magnetic field $\vec{B}$ must necessarily be uniform in R.

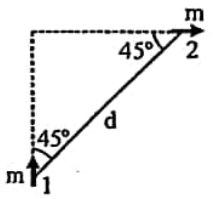
(c) There are no sources for electric charges and currents in R.

(d) The electric field $\vec{E}$ is necessarily perpendicular to the magnetic field $\vec{B}$ at every point in R.

53. An insulating sphere of radius a carries a charge density $\rho(\vec{r})=\rho_0(a^2-r^2)\cos\theta; r<a$. The leading order term for the electric field at a distance d, far away from the charge distribution, is proportional to

(a) d^{-1} (b) d^{-2} (c) d^{-3} (d) d^{-4}

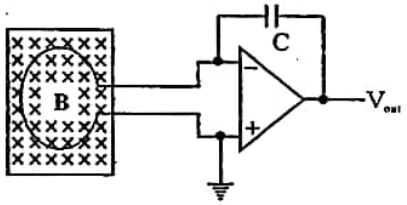
54. Two magnetic dipoles of magnitude m each are placed in a plane as shown



The energy of interaction is given by

(a) Zero (b) $\frac{\mu_0}{4\pi}\frac{m^2}{d^3}$ (c) $\frac{3\mu_0}{2\pi}\frac{m^2}{d^3}$ (d) $-\frac{3\mu_0}{8\pi}\frac{m^2}{d^3}$

55. Consider a conducting loop of radius a and total loop resistance R placed in a region with a magnetic field B thereby enclosing a flux ϕ_0. The loop is connected to an electronic circuit as shown, the capacitor being initially uncharged.



(a) ϕ_0 (b) u (c) R (d) C

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Linked Answer Questions:

Statement for Linked Answer Q.56 and Q.57.

Consider the propagation of electromagnetic waves in a linear, homogenous and isotropic material medium with electric permitivity ε, and magnetic permeability μ.

56. For a plane wave of angular frequency ω and propagation vector $\vec{k}$ propagating in the medium Maxwell's equations reduce to

(a) $\vec{k}.\vec{E}=0;\ \vec{k}.\vec{H}=0;\ \vec{k}\times\vec{E}=\omega\varepsilon\vec{H};\ \vec{k}\times\vec{H}=-\omega\mu\vec{E}$

(b) $\vec{k}.\vec{E}=0;\ \vec{k}.\vec{H}=0;\ \vec{k}\times\vec{E}=-\omega\varepsilon\vec{H};\ \vec{k}\times\vec{H}=\omega\mu\vec{E}$

(c) $\vec{k}.\vec{E}=0;\ \vec{k}.\vec{H}=0;\ \vec{k}\times\vec{E}=-\omega\mu\vec{H};\ \vec{k}\times\vec{H}=\omega\varepsilon\vec{E}$

(d) $\vec{k}.\vec{E}=0;\ \vec{k}.\vec{H}=0;\ \vec{k}\times\vec{E}=\omega\mu\vec{H};\ \vec{k}\times\vec{H}=-\omega\varepsilon\vec{E}$

57. If ε and μ assume negative values in a certain frequency range, then the directions of the propagation vector $\vec{k}$ and the Poynting vector $\vec{S}$ in that frequency range are related as

(a) $\vec{k}$ and $\vec{S}$ are parallel

(b) $\vec{k}$ and $\vec{S}$ are anti-parallel.

(c) $\vec{k}$ and $\vec{S}$ are perpendicular to each other

(d) $\vec{k}$ and $\vec{S}$ make an angle that depends on the magnitude of $|\varepsilon|$ and $|\mu|$.

58. Consider an inifinite horizontal surface with fixed surface charge density σ, where $\hat{n}$ is the upward normal to the surface. If an electric field $\vec{E}_b = E\hat{n}$ is applied from below, the electric field $\vec{E}_a$ in the region above the surface is:

(a) $\vec{E}_a=\vec{E}_b-\frac{\sigma}{2\varepsilon_0}\hat{n}$ (b) $\vec{E}_a=\vec{E}_b+\frac{\sigma}{2\varepsilon_0}\hat{n}$ (c) $\vec{E}_a=\vec{E}_b-\frac{\sigma}{\varepsilon_0}\hat{n}$ (d) $\vec{E}_a=\vec{E}_b+\frac{\sigma}{\varepsilon_0}\hat{n}$

59. A charged particle is travelling in the positive x-direction with a constant velocity. An observer located at a point P on the y-axis observes the electric field due to this charge. Let $\hat{e}(t)$ be the unit vector along the electric field at any time t, and $\hat{n}(t)$ the unit vector in the direction of the position vector of the charge with respect to the observer. Then

(a) $\hat{e}(t)$ lags behind $\hat{n}(t)$ (b) $\hat{e}(t)$ leads $\hat{n}(t)$

(c) $\hat{e}(t)$ is always in the same direction as $\hat{n}(t)$

(d) $\hat{e}(t)$ is always perpendicular to $\hat{n}(t)$

60. A current carrying loop lying in the plane of the paper is in the shape of equilateral triangle of side a. It carries a current I in the clockwise sense. If $\hat{k}$ denotes the outward normal to the plane of the paper, the magnetic moment $\vec{m}$ due to the current loop is:

(a) $\vec{m}=a^2I\hat{k}$ (b) $\vec{m}=-\frac{1}{2}a^2I\hat{k}$ (c) $\vec{m}=\frac{\sqrt{3}}{2}a^2I\hat{k}$ (d) $\vec{m}=-\frac{\sqrt{3}}{4}a^2I\hat{k}$

61. An electric point charge +q is placed at the point (1, 1) of the xy-plane in which two grounded semi-infinite conducting plates along the positive x and y-axes meet. The electric potential in the positive quadrant at a large distance r goes as

(a) $V(r)\sim r^{-1}$ (b) $V(r)\sim r^{-2}$ (c) $V(r)\sim r^{-3}$ (d) $V(r)\sim r^{-4}$

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62. In a given frame of reference, it is found that the electric field $\vec{E}(\vec{r},t)$ and the magnetic field $\vec{B}(\vec{r},t)$ are perpendicular to each other at all points, i.e. $\vec{E}(\vec{r},t).\vec{B}(\vec{r},t)=0$. If the fields observed in any other inertial frame are $\vec{E}'$ and $\vec{B}'$, then

(a) $\vec{E}'\|\vec{B}'$ at all points
(b) $\vec{E}'.\vec{B}'<0$ at all points.
(c) $\vec{E}'.\vec{B}'>0$ at all points
(d) $\vec{E}'.\vec{B}'=0$ at all points

63. Given any arbitrary electric and magnetic fields $\vec{E}(\vec{r},t)$ and $\vec{B}(\vec{r},t)$, it is always possible to choose the scalar potential $\phi(\vec{r},t)$ and vector potential $\vec{A}(\vec{r},t)$ such that

(a) $\vec{A}(\vec{r},t)$ is identically zero.

(b) $\phi(\vec{r},t)$ is identically zero.

(c) $|\vec{A}(\vec{r},t)|$ is any given non-zero constant,

(d) The conditions $\nabla.\vec{A}=0$ and $\frac{1}{c}\frac{\partial\phi}{\partial t}+\nabla.\vec{A}=0$ are simultaneously satisfied.

64. In a certain region, R, Maxwell's equations for the electric and magnetic fields are given by

$$\nabla.\vec{E}=0,\ \nabla.\vec{B}=0,\ \nabla\times\vec{E}=-\frac{\partial\vec{B}}{\partial t},\ \nabla\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$$

We may conclude that:
(a) Both the scalar and the vector potential are necessarily constant in the region R.
(b) The electric field $\vec{E}$ and the magnetic field $\vec{B}$ must necessarily be uniform in R.
(c) There are no sources for electric charges and currents in R.
(d) The electric field $\vec{E}$ is necessarily perpendicular to the magnetic field $\vec{B}$ at every point in R.

65. The magnitude of vector potential at a point $r(r<R)$ in an infinite solenoid with N-turns per unit length, radius R and carrying a current I, is given by

(a) $A=\mu_0 N I r^2$ (b) $A=\frac{\mu_0 N I r^2}{2}$ (c) $A=\mu_0 N I r$ (d) $A=\frac{\mu_0 N I r}{2}$

66. The gauge transformations of the scalar and vector potentials that leave the electric and magnetic field invariant are

(a) $\vec{A}\to\vec{A}'=A-\frac{\partial\Lambda}{\partial t}$, $\phi\to\phi'=\phi+\nabla\Lambda$

(b) $\vec{A}\to\vec{A}'=A+\nabla\Lambda$, $\phi\to\phi'=\phi-\frac{\partial\Lambda}{\partial t}$

(c) $\vec{A}\to\vec{A}'=A-\nabla\Lambda$, $\phi\to\phi'=\phi-\frac{\partial\Lambda}{\partial t}$

(d) $\vec{A}\to\vec{A}'=\vec{A}+\nabla\Lambda$, $\phi\to\phi'=\phi+\frac{\partial\Lambda}{\partial t}$

67. For plane electromagnetic waves varying in time as $e^{-i\omega t}$, the time averaged Poynting vector is:

(a) $\frac{1}{2}R_e(\vec{E}\times\vec{H})$ (b) $R_e(\vec{E}\times\vec{H})$ (c) $\frac{1}{2}R_e(\vec{E}\times\vec{H})$ (d) $\frac{1}{2}(R_e\vec{E})\times(R_e\vec{H})$

68. A dipole is formed by charges q and –q. The energy radiated by the dipole is maximum.
(a) Along the line joining the charges
(b) Along the line perpendicular to the dipole and passing midway between the dipole.
(c) Along the line inclined to the dipole axis at +45°.
(d) At the centre of the dipole.

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69. The electric field of an electric dipole $\vec{p}$ at a distance $\vec{r} = r\hat{r}$ where $\hat{r}$ is a unit vector along $\vec{r}$ is proportional to

(a) $[3\hat{r}.\vec{p}]/r^2$ (b) $[3\vec{r}.\vec{p}]/r^3$ (c) $3[(\hat{r},\vec{p})\hat{r}-\vec{p}]/r^3$ (d) $[3(\hat{r}.\vec{p})\hat{r}-\vec{p}]/r^3$

70. A large charged copper sheet is surrounded by a dielectric medium of dielectric constant $\in$. At any point on the flat surface of the sheet.

(a) The normal component of $\vec{E}$ is zero. (b) The normal component of $\vec{E}$ is not zero.

(c) The tangential component of $\vec{E}$ is zero. (d) The tangential component of $\vec{E}$ is not zero.

71. Magnetic induction $|B|$ due to current I in a coil of radius R placed in y-z plane at a distance X along the axis of the coil is given by $\frac{\mu_0 I}{2}\frac{R^2}{(R^2+X^2)^{3/2}}$. Another similar coil of radius R, carrying equal current I is placed in the y-z plane at a distance 2R from the first coil along the same axis. The value of $|B|$ at a point midway between the two coils and on the x-axis is:

(a) $\frac{\mu_0 I}{2\sqrt{2}\,R}$ (b) $\frac{\mu_0 I R}{2\sqrt{2}}$ (c) 0 (d) $\frac{\mu_0 I}{4\sqrt{2}\,R}$

72. A metal rod AB rotates clockwise in the plane of the paper about the end B with an angular velocity ω in a uniform magnetic field emerging out of the plane of the paper normally. The end B about which the rod rotates will be

(a) Positive with respect to the end A (b) Negative with respect to the end A.

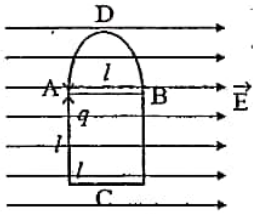
(c) Having same potential as the remaining part of the rod.

(d) Having same potential as the end B, but the centre of the rod will be at higher potential.

73. An electromagnetic wave travelling with speed V_i is incident on an interface of two media parallel to x-z plane. The magnetic field vector of the incident wave given by $\vec{B}_i(x,t) = \hat{k}\frac{E_{0T}}{V_i}e^{i(k_1 x - wt)}$. The magnetic field vector $\vec{B}(x,t)$ of the transmitted wave is:

(a) $\hat{k}\frac{E_{0T}}{V_2}e^{i(k_2 x - wt)}$ (b) $-\hat{k}\frac{B_{0T}}{V_2}e^{i(k_2 x - wt)}$ (c) $\hat{j}V_2 B_{0T}e^{i(k_2 x + wt)}$ (d) $\hat{j}V_2 B_{0T}e^{i(k_2 x - wt)}$

74. A charge q is taken from point A to point B along two different paths ACB and ADB in an uniform electric field.



The difference in the work done between these two paths is:

(a) $3qlE-(\pi/2)lqE$ (b) 0 (c) $\frac{1}{2}\pi lqE$ (d) $3qlE$

75. An electric dipole $\vec{p}$ located in a uniform electric field with its direction along the electric field $\vec{E}$. The work required to rotate the dipole through 180° is:

(a) $2(\vec{p}.\vec{E})$ (b) $\vec{p}.\vec{E}$ (c) $\vec{p}\times\vec{E}$ (d) $2(\vec{p}\times\vec{E})$

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76. The angular distribution of the average power radiated from a short dipole antenna of length d, is dependent on d and polar angle θ. This dependence is proportional to
(a) $\sin^2\theta$ (b) $d\sin^2\theta$ (c) $d^2\sin^2\theta$ (d) $d\sin\theta$

77. Maxwell's equations can be written in terms of two coupled equations satisfied by the vector potential $\bar{A}$ and scalar potential ϕ. The Lorentz gauge which decouples these equations is given by
(a) $\bar{\nabla}.\bar{A}=0$ (b) $\nabla^2\phi=\frac{1}{c^2}\frac{\partial^2\bar{A}}{\partial t^2}$ (c) $\bar{\nabla}.\bar{A}=-\frac{1}{c^2}\frac{\partial\phi}{\partial t}$ (d) $\bar{\nabla}.\bar{A}=\frac{1}{c}\frac{\partial\phi}{\partial t}$

78. An electromagnetic field is described by the scalar potential $\phi = ay$ and vector potential $\bar{A}=\hat{k}\times t$ where a is a constant. The electric field $\bar{E}$ is:
(a) Linearly polarized (b) Circularly polarized
(c) Elliptically polarized (d) Unpolarized.

79. An electron moves with velocity $\hat{v}=\hat{j}.v_0$ under the combined influence of $\bar{E}=\hat{i}E_0$ and $\bar{B}=-\hat{k}B_0$ fields. The force on the electron is in the
(a) Y direction (b) Z direction (c) YZ plane (d) X direction

80. An electromagnetic wave is elliptically polarized in the X-Y plane. The direction of the Poynting vector is in the
(a) Z-direction (b) X-direction (c) Y-direction (d) XY-plane

81. The electrostatic potential is given by,
$\Phi = 0$ at $x = 0$ and $x = a$; $\Phi = V$ $0 \le x \le a$.
Then Φ is given by $\Phi=\sum_{n=1}^{\infty}A_n\sin(\alpha x)$ where α is:
(a) $\frac{n\pi}{2}$ (b) $\frac{n\pi}{a}$ (c) $\frac{na}{\pi}$ (d) $\frac{na}{2\pi}$

82. A certain charge distribution is symmetric about the Z-axis which is the principal axis. The off-diagonal quadrupole tensor elements Q_{ij} are all zero. It is given that $Q_{11}=1$, then
(a) $Q_{33}=-2$ (b) $Q_{22}=-1$ (c) $Q_{33}=1$ (d) $Q_{22}=-2$

83. Which of the following is Lorentz Invarient
(a) $E^2-B^2C^2$ (b) $\bar{E}\times\bar{B}$ (c) E^2-BC^2 (d) $\bar{E}\times\bar{C}$

84. For a co-axial TE mode
(a) $E_z\neq 0, H_z=0$ (b) $E_z=0, H_z\neq 0$
(c) $E_z=0, H_z=0$ (d) $E_z\neq 0, H_z=1$

85. Polarisation can be achieved by
(a) Beam splitter (b) Grating (c) Plane Mirror (d) None of these

86. The poynting vector in the radial direction, at the surface of a long straight wire, of radius b and resistance per unit length R, carrying a current I is:
(a) $\frac{-RI^2}{2\pi b}\hat{r}(\text{inward})$ (b) $\frac{RI^2}{2\pi b}\hat{r}(\text{outward})$
(c) $\frac{bI}{2\pi R}\hat{r}(\text{inward})$ (d) $\frac{2\pi I}{Rb}\hat{r}(\text{inward})$

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87. Of A and V are vector and scalar potential $v(r,t)=0$, $A(r,t)=\frac{-q}{4\pi\epsilon_0}\frac{t\bar{r}}{r^2}$. Scalar function $\lambda=\frac{-q}{4\pi\epsilon_0}\frac{t}{r^2}$

Due to gauge transformation transformed potential is

(a) $v'(r,t)=0 \quad A(r,t)=\frac{q}{4\pi\epsilon_0}t\frac{1}{r^2}$

(b) $v'(r,t)=\frac{q}{4\pi\epsilon_0 r^2} \quad A(r,t)=\frac{q}{4\pi\epsilon_0}t\frac{1}{r^2}$

(c) $v'(r,t)=\frac{-q}{4\pi\epsilon_0}\frac{1}{r^2} \quad A'(r,t)=\frac{-qt}{4\pi\epsilon_0}\frac{1}{r^2}$

(d) $v'(r,t)=\frac{q}{4\pi\epsilon_0}\frac{1}{r^2} \quad A'(r,t)=\frac{qt}{4\pi\epsilon_0 r^2}$

88. A medium with refractive index $n(\omega)$, where ω is the frequency, is said to posses anomalous dispersion when

(a) $\frac{\partial n}{\partial\omega}>0$ (b) $\frac{\partial n}{\partial\omega}<0$ (c) $\frac{\partial^2 n}{\partial\omega^2}>0$ (d) $\frac{\partial^2 n}{\partial\omega^2}<0$

89. The field $\bar{F}=yz\hat{i}+zx\hat{j}+xy\hat{k}$ may represent

(a) Only magnetostatic field
(b) Only an electrostatic field
(c) Both electrostatic and magnetostatic field
(d) Neither electrostatic nor magnetostatic field.

90. Electromagnetic wave in vacuum is given by $\bar{E}(\bar{r},t)=\hat{i}E_0e^{-i(\omega t-\bar{k}.\bar{x})}$. Magnetic field $\bar{B}$ is:

(a) $\hat{j}E_0\hat{k}\exp\left[-i(\omega t-\bar{k}.\bar{x})\right]$
(b) $\hat{j}E_0\exp\left[-i(\omega t-k_z z)\right]$
(c) $\hat{k}E_0\exp\left[-i(\omega t-\bar{k}.\bar{x})\right]$
(d) $\hat{j}E_0\exp\left[-i(\omega t-\bar{k}.\bar{x})\right]$

91. In a non-magnetic dielectric medium with dielectric constant $\varepsilon_r=4$, the electric field of a propagating plane wave with $\omega=10^8$ rad/s is given by, $\bar{E}=\left(-\hat{i}+\sqrt{3}\hat{j}\right)\exp\left[j(\omega t-\bar{k}.\bar{r})\right]$. The propagation vector $\bar{k}$ (in units of m^{-1}) is given by

(a) $\bar{k}=\frac{1}{\sqrt{3}}\hat{i}+\frac{1}{3}\hat{j}$
(b) $\bar{k}=\frac{1}{3}\hat{z}$
(c) $\bar{k}=\frac{1}{2\sqrt{3}}\hat{i}+\frac{1}{6}\hat{j}$
(d) $\bar{k}=-\frac{1}{\sqrt{3}}\hat{i}+\frac{1}{3}\hat{j}$

92. Two small circular loops, each of area 1 cm^2 carry currents 1A and 2A respectively. They are placed in a plane at a distance of 5 meters from each other. If one of the loops is lifted 5 meters in the vertical direction while maintaining it flat, the electrical work done in the process is (μ_0 is the magnetic permeability of vacuum)

(a) $2.75\times10^{-9}\ \mu_0^2\ J$
(b) $1.46\times10^{-10}\ \mu_0^2\ J$
(c) $1.88\times10^{-10}\ \mu_0^2\ J$
(d) $4.74\times10^{-9}\ \mu_0^2\ J$

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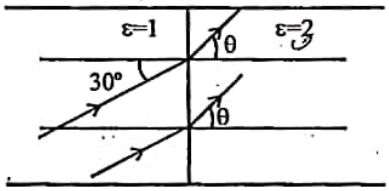
93. A large slab consists of two materials with dielectric constants 1 and 3 divided by a plane interface as shown in the figure. An electric field exists in this slab, which uniformly makes an angle of 30° with the normal to the interface on the left side of the $(\varepsilon = 1)$. The angle the field makes on the other side of the interface is:



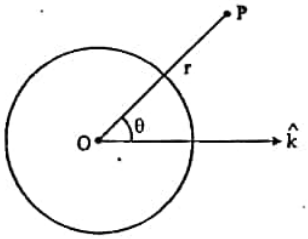
(a) $\tan^{-1}(3)$ (b) $\sin^{-1}\left(\frac{1}{2\sqrt{3}}\right)$ (c) 60° (d) $\tan^{-1}(1/3)$

94. A particle of mass m and charge q is constrained to move along a straight line joining two other equal charges q fixed at $x = \pm a$. The time period of small oscillation is:

(a) $T = \frac{2\pi a}{q}\sqrt{\varepsilon_0 am}$ (b) $T = \frac{4\pi a}{q}\sqrt{r\varepsilon_0 am}$ (c) $T = \frac{a}{q}\sqrt{r\varepsilon_0 am}$ (d) $T = \frac{2\pi a}{q}\sqrt{\varepsilon_0 am}$

95. A spherical conductor of radius a is placed in a uniform electric field $\vec{E} = E_0\hat{k}$. The potential at a point $P(r,\theta)$ for r > a, is given by, $\varphi(r,\theta) = \text{constant} - E_0 r\cos\theta + \frac{E_0 a^3}{r^2}\cos\theta$

Where 'r' is the distance of P from the centre O of the sphere and θ is the angle OP makes with the z-axis.



The charge density on the sphere at $\theta = 30°$ *is* :

(a) $3\sqrt{3}\,\varepsilon_0 E_0/2$ (b) $3\varepsilon_0 E_0/2$ (c) $\sqrt{3}\varepsilon_0 E_0/2$ (d) $\varepsilon_0 E_0/2$

Statement for Linked Answer Questions 96 and 97:

A plane electromagnetic wave has the magnetic field given by $\vec{B}(x,y,z,t) = B_0\sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\hat{k}$

Where k is the wave number and $\hat{i}, \hat{j}$ and $\hat{k}$ are the Cartesian unit vectors is x, y and z directions, respectively.

96. The electric field $\vec{E}(x,y,z,t)$ corresponding to the above wave is given by

(a) $cB_0\sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\frac{(\hat{i}-\hat{j})}{\sqrt{2}}$ (b) $cB_0\sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$

(c) $cB_0\sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\hat{i}$ (d) $cB_0\sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\hat{j}$

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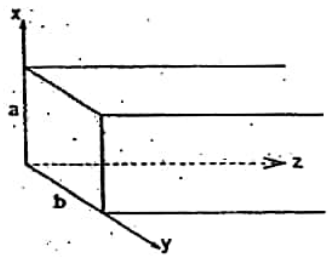
97. The average Poynting vector is given by

(a) $\frac{cB_0^2}{2\mu_0}\frac{(\hat{i}-\hat{j})}{\sqrt{2}}$ (b) $-\frac{cB_0^2}{2\mu_0}\frac{(\hat{i}-\hat{j})}{\sqrt{2}}$ (c) $\frac{cB_0^2}{2\mu_0}\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$ (d) $-\frac{cB_0^2}{2\mu_0}\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$

98. A static, spherically symmetric charge distribution is given by $\rho(r)=\frac{A}{r}e^{-kr}$ where A and K are positive constants. The electrostatic potential corresponding to this charge distribution varies with r as

(a) $r\,e^{-Kr}$ (b) $\frac{1}{r}e^{-Kr}$ (c) $\frac{1}{r^2}e^{-Kr}$ (d) $\frac{1}{r}\left(1-e^{-Kr}\right)$

99. The magnetic field of the TE_{11} mode of a rectangular waveguide of dimensions a×b as shown in the figure is given by $H_z = H_0\cos(0.3\pi x)\cos(0.4\pi y)$, where x and y are in cm.



A. The dimensions of the waveguide are

(a) a = 3.33 cm, b = 2.50 cm (b) a = 0.40 cm, b = 0.30 cm

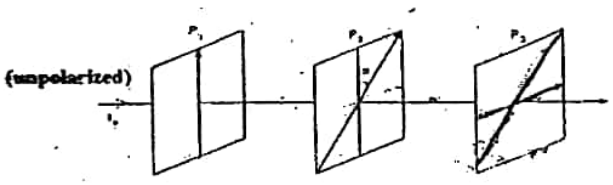
(c) a = 0.80 cm, b = 0.60 cm (d) a = 1.66 cm, b = 1.25 cm

B. The entire range of frequencies f for which the TE_{11} mode will propagate is:

(a) 6.0 GHz < f < 7.5 GHz (b) 7.5 GHz < f < 9.0 GHz

(c) 7.5 GHz < f < 12.0 GHz (d) 7.5 GHz < f

100. Consider three polarizers P_1, P_2 and P_3 placed along an axis as shown in the Figure.



The pass axis of P_1 and P_3 are at right angles to each other while the pass axis of P_2 makes an angle θ with that of P_1. A beam of unpolarized light of intensity I_0 is incident on P_1 as shown. The intensity of light emerging from P_3 is

(a) 0 (b) $\frac{I_0}{2}$ (c) $\frac{I_0}{8}\sin^2 2\theta$ (d) $\frac{I_0}{4}\sin^2 2\theta$

101. Four equal point charges are kept fixed at the four vertices of a square. How many neutral points (i.e., points where the electric field vanishes will be found inside the square?

(a) 3 (b) 4 (c) 5 (d) 7

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102. In a Young's double slit interference expriment, the slits are at a distance 2L from each other and the screen is at a distance D from the slits. If a glass slab of refractive index μ and thickness d is placed in the path of one of the beams, the minimum value of d for the central fringe to be dark is

(a) $\frac{\lambda D}{(\mu-1)\sqrt{D^2+L^2}}$ (b) $\frac{\lambda D}{(\mu-1)L}$ (c) $\frac{\lambda}{(\mu-1)}$ (d) $\frac{\lambda}{2(\mu-1)}$

103. Consider a solenoid of radius R with n turns per unit length, in which a time dependent current $I = I_0 \sin\omega t$ (where $\omega R/c \ll 1$) flows. The magnitude of the electric field at a perpendicular distance $r<R$ from the axis of symmetry of the solenoid, is:

(a) 0 (b) $\frac{1}{2r}\omega\mu_0 n I_0 R^2 \cos\omega t$

(c) $\frac{1}{2}\omega\mu_0 n I_0 r \sin\omega t$ (d) $\frac{1}{2}\omega\mu_0 n I_0 r \cos\omega t$

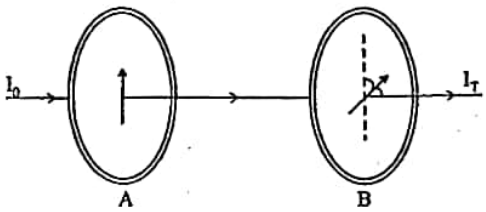
104. A constant electric current I in an infinitely long straight wire is suddenly switched on at $t=0$. The vector potential at a perpendicular distance r from the wire is given by $\vec{A} = \frac{\hat{k}\mu_0 I}{2\pi} \ell n\left[\frac{1}{r}\left(ct+\sqrt{c^2t^2-r^2}\right)\right]$. The electric field at a distance $r(<ct)$ is:

(a) 0 (b) $\frac{\mu_0 I}{2\pi t}\frac{1}{\sqrt{2}}\left(\hat{i}-\hat{j}\right)$ (c) $\frac{c\mu_0 I}{2\pi\sqrt{c^2t^2-r^2}}\frac{1}{\sqrt{2}}\left(\hat{i}+\hat{j}\right)$ (d) $-\frac{c\mu_0 I}{2\pi\sqrt{c^2t^2-r^2}}\hat{k}$

105. A static charge distribution gives rise to an electric field of the form $\vec{E} = \alpha\left(1-e^{-r/R}\right)\frac{\hat{r}}{r^2}$, where α and R are positive constants. The charge contained within a sphere of radius R, centred at the origin is:

(a) $\pi\alpha\varepsilon_0\frac{e}{R^2}$ (b) $\pi\alpha\varepsilon_0\frac{e^2}{R^2}$ (c) $4\pi\alpha\varepsilon_0\frac{R}{e}$ (d) $\pi\alpha\varepsilon_0\frac{R^2}{e}$

106. Unpolarised light of intensity I_0 Passes successively through two identical linear polarisers A and B, placed such that their polarisation axes are at an angle of 45° (see figure) with respect to one another.



Assuming A and B to be perfect polarisers (i.e. no absorption losses), the intensity of the transmitted light will be I_T =

(a) $I_0/4$ (b) $I_0/2\sqrt{2}$ (c) $I_0/2$ (d) $I_0/\sqrt{2}$

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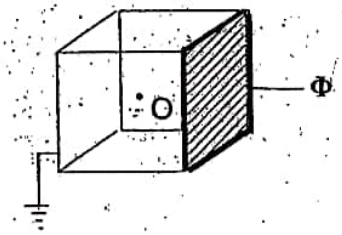
107. Three equal chrages Q are successively brought from infinity and each is placed at one of the three vertices of an equilateral tringle. Assuming the rest of the Universe as a whole to be neutral, the energy E_0 of the electrostatic field will increase, successively, to

$E_0 + \Delta_1$, $E_0 + \Delta_1 + \Delta_2$, $E_0 + \Delta_1 + \Delta_2 + \Delta_3$

Where $\Delta_1 : \Delta_2 : \Delta_3 =$

(a) 1 : 2 : 3 : (b) 1 : 1 : 1 (c) 0 : 1 : 1 (d) 0 : 1 : 2

108. Five sides of a hollow metallic cube are grounded and the sixth side is insulated from the rest and is held at a potential Φ (see figure).



The potential at the centre O of the cube is

(a) 0 (b) $\Phi/6$ (c) $\Phi/5$ (d) $2\Phi/3$

109. If $\vec{D} = (2y^2 + z)\hat{i} + 4xy\hat{j} + x\hat{k}$, units of C/m^2, the total charge enclosed by the cube

$0 \le x < 1, 0 \le y < 1, \ 0 \le z \le 1$

(a) 2C (b) 4C (c) 0 C (d) 1C

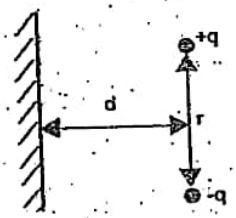
110. The electric fields of a long straight wire varies with distance r (perpendicular to the wire) as

(a) $\frac{1}{r}$ (b) In r (c) $1/r^2$ (d) $1/r^3$

111. If $\vec{V} = \hat{i} + \hat{j} + \hat{k}$, where $\hat{i}, \hat{j}$ and $\hat{k}$ are the unit vectors in three-dimensions, the value of $\vec{\nabla}.\vec{V}$ is :

(a) -3 (b) 2 (c) 0 (d) 3

112. Two equal and opposite charges are placed at a distance r from each other. A large metallic sheet is placed at a distance d from them as shown in the figure. Due to the presence of the sheet, the attractive force between the charges along the direction joining them



(a) decreases (b) increases (c) remains unchanged
(d) decreases or increases depending on the conductivity of the sheet.

113. The magnetic induction $\vec{B}$ and the field $\vec{H}$ inside a bar magnet are

(a) parallel to the bar, and opposite to each other with $\vec{B}$ directed from south to north pole
(b) parallel to each other along the bar, but their magnitude differ by a factor of permeability
(c) parallel to the bar, and opposite to each other with $\vec{B}$ directed from north to south pole
(d) parallel to each other along the bar with equal magnitude

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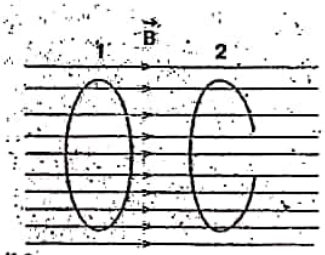
114. Two beams of light with electric field amplitudes $\hat{i}E$ and $\left(\hat{i}-2\hat{j}\right)E$ interfere at a point with path difference $\lambda/2$. The magnitude of the electric field at the point of interference is

(a) $2\sqrt{2}\,E$ (b) 0 (c) $2\,E$ (d) $\left(1+\sqrt{5}\right)E$

115. A propagating electromagnetic wave is given by $\vec{E}=E_0\left(j+i\hat{k}\right)e^{i(kx-\omega t)}$. The wave is

(a) left circularly polarized (b) right circularly polarized
(c) linearly polarized (d) elliptically polarized

116. Two conducting coils 1 and 2 (identical except that 2 is split) are placed in a uniform magnetic field as shown in the figure. The magnetic field decreases at constant rate. If the plane of the coils is perpendicular to the field lines, which of the following statements is true.



(a) an emf is induced in the split coil 2
(b) an emf is induced in both coils
(c) equal Joule heating occurs in both coils
(d) Joule heating does not occur in either coil

117. If the scalar and vector potentials $\phi(\vec{r},t),\vec{A}(\vec{r},t)$ are transformed to $\phi'(\vec{r},t)=\phi(\vec{r},t)+\phi_0 e^{-\lambda t}$ and $\vec{A}'(\vec{r},t)=\vec{A}(\vec{r},t)+\phi_0\vec{r}$ respectively, the corresponding electric and magnetic fields transform as

(a) $\vec{E}'=\vec{E},\ \vec{B}'=B_0+\phi_0\vec{r}\dfrac{e^{-\lambda t}}{r}$ (b) $\vec{E}'=\vec{E}+\phi_0\vec{r},\ \vec{B}'=\vec{B}_0+\phi_0\vec{r}\ e^{-\lambda t}$

(c) $\vec{E}'=\vec{E}-\phi_0\vec{r}\ e^{-\lambda t},\ \vec{B}'=\vec{B}$ (d) $\vec{E}'=\vec{E},\quad \vec{B}'=\vec{B}$

118. For a wave propagating in an air filled metallic rectangular waveguide, the frequency and the wavevector are related as (c is the speed of light and ω_c is the cut off frequency)

(a) $c^2k^2=\omega^2+\omega_c^2$ (b) $c^2k^2=\omega^2$ (c) $c^2k^2=\omega^2-\omega_c^2$ (d) $c^2k^2=\sqrt{\omega^4-\omega_c^4}$

119. In a distortionless transmission line the attenuation constant α is frequency independent while the propagation constant depends linearly on frequency. If R, L, C and G denote the transmission line parameters, for the distortion less line

(a) $RG=\dfrac{1}{\sqrt{LC}}$ (b) $\dfrac{R}{L}=\dfrac{C}{G}$ (c) $R=\sqrt{\dfrac{L}{C}}$ (d) $\dfrac{R}{L}=\dfrac{G}{C}$

120. If $\vec{E}$ and $\vec{B}$ are the electric and magnetic fields respectively, identify the Lorentz invariant quantity from the following.

(a) $\vec{E}^2\,\vec{B}$ (b) $|\vec{E}\times\vec{B}|^2$ (c) $\vec{E}^2-c^2\vec{B}^2$ (d) $\vec{E}^2+c^2\vec{B}^2$

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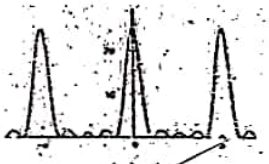
121. The diffraction pattern from a grating with N slits is shown in the figure. The value of N is

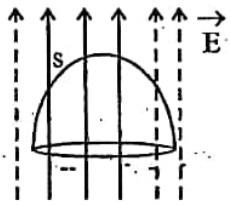


(a) 3 (b) 5 (c) 4 (d) 2

122. The one dimensional potential $V(x)$ for an electrostatic fields in a region of space which does not contain any charge has the form (in the following a and b are constants)

(a) $a\sin bx$ (b) ae^{-x^2} (c) $\frac{1}{2}ax^2$ (d) $ax+b$

123. A hemispherical surface of radius R is in a constant electric field $\vec{E}$ directed perpendicular to the base, as shown. The flux through the curved surface S of the hemisphere is



(a) 0 (b) πR^2E (c) $2\pi R^2E$ (d) $4\pi R^2E$

124. When a plane electromagnetic wave is incident angle $i = 60°$, the reflected light is completely polarized. The dielectric constant is

(a) 4/3 (b) $\sqrt{3}$ (c) 2 (d) 3

125. When a charged particle with kinetic energy E enters a region of uniform magnetic field $\vec{B}$ directed perpendicular to its velocity, it is found to move in circle of radius R. If the particle had kinetic energy 2E, the radius of the path would have been

(a) $R/\sqrt{2}$ (b) $\sqrt{2}R$ (c) $R/2$ (d) $2R$

126. A dielectric sphere of radius R carries a polarization $\vec{P} = k\vec{r}$ throughout its volume. The volume charge density ρ_b of the bound charges is

(a) $-3k$ (b) $3k$ (c) $-k$ (d) k

127. The expression $\vec{A} = \frac{B}{2}\left(-\hat{i}y + \hat{j}x\right)$ for the vector potential represents

(a) a uniform magnetic field in the z-direction (b) a non- uniform magnetic field in the z-direction
(c) a uniform magnetic field in xy-plane (d) a non-uniform magnetic field in xy-plane

128. In a region of space it is found that $\vec{\nabla}.\vec{E} = 0$ but $\vec{\nabla} \times \vec{E} \neq 0$. Which of the following statements is not true?
(a) The charge density must be zero (b) A displacement current must exist
(c) The divergence of magnetic field must be zero
(d) A time-varying magnetic field must exist

129. An electromagnetic wave propagating along the z-direction in a rectangular waveguide in the TE mode is characterized by

(a) $E_z = 0, H_z \neq 0$ (b) $H_z = 0, E_z \neq 0$ (c) $E_z = 0, H_z = 0$ (d) $E_z \neq 0, H_z \neq 0$

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130. To determine the electrostatic potential inside an enclosure with insulating walls, one needs to know the
(a) value of the potential at all points on the surface of the enclosure
(b) value of the potential at just two points on the surface of the enclosure
(c) value of the potential as well as its gradient at all points on the surface of the enclosure
(d) value of the potential and its gradient at one point on the surface

131. Consider the plane defined by $(x, y, z = 10\,m)$. If it carries a charge of $20\ nC/m^2$, what is the electric field intensity at the origin?

(a) $-720\pi\hat{k}\frac{V}{m}$ (b) $-360\pi\hat{k}\frac{V}{m}$ (c) $-72\pi\hat{k}\frac{V}{m}$ (d) $-18\,\pi\hat{k}\frac{V}{m}$

132. The electrostatic potential in a given region of space is $\phi(\bar{r}) = \frac{1}{\epsilon_0}\left[x^2 + y^2 - 2z^2\right]$. The charge density $\rho(\bar{r})$ in the region is

(a) $\frac{-x-y+4z}{r^3}$ (b) $\frac{x+y-2z}{r}$ (c) zero (d) $\frac{4}{r^2}$

133. A square loop of a thin wire with side a carries a current I. Choosing the centre of the loop to be the coordinate origin and the z-axis to be normal to the loop, the magnetostatic potential $\phi(\bar{r})$ is given as

(a) $\frac{\mu_0 I}{r^3}$ (b) $\frac{\mu_0 I a^2}{r^2}$ (c) $\frac{\mu_0 I a^2}{4\pi}\frac{z}{r^3}$ (d) $\mu_0 I a^2\left(\frac{3xy-z^2}{r^3}\right)$

134. Which of the following groups of boundary conditions is satisfied at an interface between two nonmagnetic dielectric media ? [$\bar{D}_1, \bar{E}_1, \bar{B}_1$ and $\bar{D}_2, \bar{E}_2, \bar{B}_2$ represent the displacement vector, electric field and magnetic field in region 1 and 2 respectively and $\hat{n}$ defines the unit vector normal to the interface]

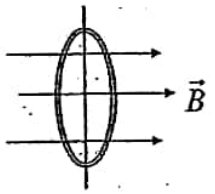
(a) $\bar{D}_1 \times \hat{n} = \bar{D}_2 \times \hat{n}$ & $\bar{B}_1 . \hat{n} = \bar{B}_2 . \hat{n}$ (b) $\bar{E}_1 . \hat{n} = \bar{E}_2 . \hat{n}$ & $\bar{B}_1 \times \hat{n} = \bar{B}_2 \times \hat{n}$

(c) $\bar{D}_1 \times \hat{n} = \bar{D}_2 \times \hat{n}$ & $\bar{B}_1 \times \hat{n} = \bar{B}_2 \times \hat{n}$ (d) $\bar{D}_1 . \hat{n} = \bar{D}_2 . \hat{n}$ & $\bar{B}_1 \times \hat{n} = \bar{B}_2 \times \hat{n}$

135. There is a uniform magnetic field B in the z-direction in a certain region of space. The corresponding vector potential is given by.

(a) $\bar{A} = Bx\,\bar{j}$ (b) $\bar{A} = \frac{B\bar{r}}{r^2}$ (c) $\bar{A} = B\bar{r}$ (d) $\bar{A} = B\left(x\bar{i} + y\bar{k}\right)$

136. A loop of wire of radius a and carrying a current I is suspended vertically in a uniform horizontal magnetic field B as shown. Calculate the work done in rotating the loop around the vertical axis through an angle π



(a) $\frac{\pi^2 I^2}{2a}$ (b) $2\pi a^2 I$ (c) $\frac{\pi a^2 I}{2}$ (d) 0

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137. The electric field of an electromagnetic wave is given by $\vec{E} = E_0\left(3\hat{i} + 4\hat{j}\right)\cos k\left(4x - 3y - ct\right)$. The directions of the magnetic field $\vec{B}$ and the poynting vector $\vec{p}$ are

(a) $-\hat{k}, \frac{4\hat{i}+3\hat{j}}{5}$ (b) $\hat{k}, \frac{4\hat{i}-3\hat{j}}{5}$ (c) $\frac{4\hat{i}-3\hat{j}}{5}, \hat{k}$ (d) $\frac{4\hat{i}-3\hat{j}}{5}, \frac{4\hat{i}+3\hat{j}}{5}$

138. A right circularly polarized beam is incident on a calcite half wave plate. The emergent wave will be
(a) linearly polarized (b) left circularly polarized
(c) elliptically polarized (d) unpolarized

139. A circular loop of wire of radius a carries an oscillating current I of frequency ω. The electric and magnetic fields at distance r much larger than a $(r >> a)$ very as

(a) $E \propto \frac{1}{r}$, $B \propto \frac{1}{r^2}$ (b) $E \propto \frac{1}{r^2}$, $B \propto \frac{1}{r^2}$ (c) $E \propto \frac{1}{r}$, $B \propto \frac{1}{r}$ (d) $E \propto \frac{1}{r^2}$, $B \propto \frac{1}{r}$

140. A microwave source of wave length $\lambda = 3$ cm is used in a double slit interference experiment. The distance D from the slits to the detector is 1m. If the distance d between the slits increases from 1mm to 5 cm, then
(a) the fringes being to overlap
(b) the central maximum becomes more intense
(c) the secondary sources at the slits lose coherence
(d) the separation between the maxima decreases.

141. The space-time dependence of the electric field of a linearly polarized light in free space is given by $\hat{x}E_0\cos(\omega t - kz)$ where E_0 ω and k are the amplitude, the angular frequency and the wavevector, respectively. The time averaged energy density associated with the electric field is

(a) $\frac{1}{4}\varepsilon_0 E_0^2$ (b) $\frac{1}{2}\varepsilon_0 E_0^2$ (c) $\varepsilon_0 E_0^2$ (d) $2\varepsilon_0 E_0^2$

142. A plane electromagnetic wave traveling in free space is incident normally on a glass plate of refractive index 3/2. If there is no absorption by the glass, Its reflectivity is
(a) 4% (b) 16 % (c) 20% (d) 50%

143. The electric and the magnetic fields $\vec{E}(z,t)$ and $\vec{B}(z,t)$, respectively corresponding to the scalar potential $\phi(z,t) = 0$ and vector potential $\vec{A}(z,t) = \hat{i}tz$ are

(a) $\vec{E} = \hat{i}z$ and $\vec{B} = -\hat{j}t$ (b) $\vec{E} = \hat{i}z$ and $\vec{B} = \hat{j}t$ (c) $\vec{E} = -\hat{i}z$ and $\vec{B} = -\hat{j}t$ (d) $\vec{E} = -\hat{i}z$ and $\vec{B} = \hat{j}t$

144. A plane polarized electromagnetic wave in free space at time t = 0 is given by $\vec{E}(x,z) = 10\hat{j}\exp\left[i(6x + 8z)\right]$. The magnetic field $\vec{B}(x,z,t)$ is given by

(a) $\vec{B}(x,z,t) = \frac{1}{c}\left(6\hat{k} - 8\hat{i}\right)\exp\left[i(6x + 8z - 10ct)\right]$.

(b) $\vec{B}(x,z,t) = \frac{1}{c}\left(6\hat{k} + 8\hat{i}\right)\exp\left[i(6x + 8z - 10ct)\right]$.

(c) $\vec{B}(x,z,t) = \frac{1}{c}\left(6\hat{k} - 8\hat{i}\right)\exp\left[i(6x + 8z - ct)\right]$.

(d) $\vec{B}(x,z,t) = \frac{1}{c}\left(6\hat{k} + 8\hat{i}\right)\exp\left[i(6x + 8z + ct)\right]$.

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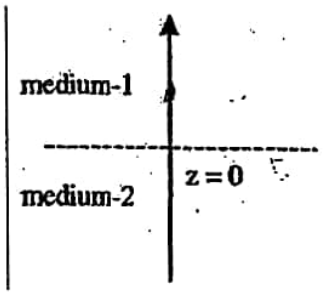
145. Two infinitely extended homogeneous isotropic dielectric media (medium -1 and medium –2 with dielectric constants $\frac{\varepsilon_1}{\varepsilon_0}=2$ and $\frac{\varepsilon_2}{\varepsilon_0}=5$, respectively) meet at the $z=0$ plane as shown in the figure. A uniform electric field exists everywhere. For $z \geq 0$, the electric field is given by $\vec{E}_1 = 2\hat{i}-3\hat{j}+5\hat{k}$. The interface separating the two media is charge free.
The electric displacement vector in the medium-2 is given by



(a) $\overrightarrow{D_2} = \varepsilon_0\left[10\hat{i}+15\hat{j}+10\hat{k}\right]$ (b) $\overrightarrow{D_2} = \varepsilon_0\left[10\hat{i}-15\hat{j}+10\hat{k}\right]$

(c) $\overrightarrow{D_2} = \varepsilon_0\left[4\hat{i}-6\hat{j}+10\hat{k}\right]$ (d) $\overrightarrow{D_2} = \varepsilon_0\left[4\hat{i}+6\hat{j}+10\hat{k}\right]$

Statement for Linked Answer Q.146 and Q. 147

In a hydrogen atom, consider that the electronic charge is uniformly distributed in a spherical volume of radius $a\left(=0.5\times10^{-10}\text{m}\right)$ around the proton. The atom is placed in a uniform electric field $E=30\times10^5$ V/m. Assume that the spherical distribution of the negative charge remains undistorted under the electric field.

146. In the equilibrium condition, the separation between the positive and the negative charge centers is

(a) 8.66×10^{-16} m (b) 2.60×10^{-15} m (c) 2.60×10^{-16} m (d) 8.66×10^{-15} m

147. The polarizability of the hydrogen atom in unit of $\left(C^2m/N\right)$ is

(a) 2.0×10^{-40} (b) 1.4×10^{-41} (c) 1.4×10^{-40} (d) 2.0×10^{-39}

148. An observer in an inertial frame that a point P the electric field vanishes but the magnetic field does not. This implies that in any other initial frame the electric field $\vec{E}$ and the magnetic field $\vec{B}$ satisfy

(a) $|\vec{E}|^2=|B|^2$ (b) $\vec{E}.\vec{B}=0$ (c) $\vec{E}\times\vec{B}=0$ (d) $\vec{E}=0$

149. A magnetic field $\vec{B}=B_0\left(\hat{i}+2\hat{j}-4\hat{j}\right)$ exists at a point. If a test charge moving with a velocity $\vec{\upsilon}=\upsilon_0\left(3\hat{i}-\hat{j}+2\hat{k}\right)$ experiences no force at a certain point. The electric field at that point in SI units is

(a) $\vec{E}=-\upsilon_0B_0\left(3\hat{i}-2\hat{j}-4\hat{k}\right)$ (b) $\vec{E}=-\upsilon_0B_0\left(\hat{i}+\hat{j}+7\hat{k}\right)$

(c) $\vec{E}=\upsilon_0B_0\left(14\hat{j}+7\hat{k}\right)$ (d) $\vec{E}=-\upsilon_0B_0\left(14\hat{j}+7\hat{k}\right)$

150. A circular conducting ring of radius 'R' rotates with constant angular velocity ω about its diameter placed along the x-axis. A uniform magnetic field B is applied along the y-axis. If at time $t=0$ the ring is entirely in the xy- plane, the emf induced in the ring at time $t>0$ is

(a) $B\omega^2\pi R^2t$ (b) $B\omega\pi R^2\tan(\omega t)$ (c) $B\omega\pi R^2\sin(\omega t)$ (d) $B\omega\pi R^2\cos(\omega t)$

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151. An electric field in a region is given by $\vec{E}(x,y,z) = ax\hat{i} + cz\hat{j} + 6by\hat{k}$. For which of a, b, c does this represent an electrostatic field ?
(a) 13, 1, 12 (b) 17, 6, 1 (c) 13, 1, 6 (d) 45, 6, 1

152. A cube has a constant electric potential V on its surface. If there are no charges inside the cube. the potential at the center of the cube is
(a) V (b) V/8 (c) 0 (d) V/6

153. Consider a particle of electric charge e and mass moving under the influence of constant horizontal electric field E and constant vertical gravitational field described by acceleration due to gravity 'g'. If the particle starts from rest, what will be its trajectory ?
(a) Parabolic (b) elliptic (c) straight line (d) circular

154. A small magnet is dropped down a long vertical copper tube in a uniform gravitational field. After a long time, the magnet
(a) Attains a constant velocity (b) moves with a constant acceleration
(c) moves with a constant deceleration (d) executes simple harmonic motion.

155. A point charge +q placed at (0, 0, d) above a grounded infinite conducting plane defined by z = 0. There are no charges present anywhere else. What is the magnitude of electric field at (0, 0, –d) ?
(a) $q/(8\pi\varepsilon_0 d^2)$ (b) $-\infty$ (c) 0 (d) $q/(16\pi\varepsilon_0 d^2)$

156. When unpolarised light is incident on a glass plate at a particular angle, it is observed that the reflected beam is linearly polarised. What is the angle of the refracted beam with respect to the surface normal ? Refractive index of glass is 1.52
(a) 56.7° (b) 33.4° (c) 23.3°
(d) The light is completely reflected and there is no refracted beam.

157. A time-dependent magnetic field $\vec{B}(t)$ is produced in a circular region of space, infinitely long and of radius R. The magnetic field is given as $\vec{B} = B_0 t\hat{z}$ for $0 \le r < R$ and is zero for $r > R$. Where B_0 is a positive constant. The electric field for $r > R$ is
(a) $\frac{B_0 R^2}{r}\hat{r}$ (b) $\frac{B_0 R^2}{2r}\hat{\theta}$ (c) $-\frac{B_0 R^2}{r}\hat{r}$ (d) $-\frac{B_0 R^2}{2r}\hat{\theta}$

158. The magnetic field corresponding to the vector potential, $\vec{A} = \frac{1}{2}\vec{F}\times\vec{r} + \frac{10}{r^3}\vec{r}$ where $\vec{F}$ is a constant vector, is
(a) $\vec{F}$ (b) $-\vec{F}$ (c) $\vec{F} + \frac{30}{r^4}\vec{r}$ (d) $\vec{F} - \frac{30}{r^4}\vec{r}$

159. An electromagnetic wave is incident on a water-air interface. The phase of the perpendicular component of the electric field, $E_\perp$, of the reflected wave into the water is found to remain the same for ail angles of incidence. The phase of the magnetic field H.
(a) does not change (b) changes by $3\pi/2$ (c) changes by $\pi/2$ (d) changes by π

160. The magnetic field at a distance R from a long straight wire carrying a steady current I is proportional to
(a) IR (b) I/R^2 (c) I^2/R^2 (d) I/R

161. Which of the following quantities is Lorentz invariant?
(a) $|E\times B|^2$ (b) $|E|^2 - |B|^2$ (c) $|E|^2 + |B|^2$ (d) $|E|^2|B|^2$

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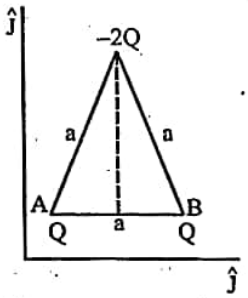
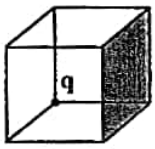
162. Charges Q, Q and -2Q are placed on the vertices of an equilateral triangle ABC of sides of length a, as shown in the figure



The dipole moment of this configuration of charges, irrespective of the choice of origin, is

(a) $+2aQ\hat{i}$ (b) $+\sqrt{3}aQ\hat{j}$ (c) $-\sqrt{3}aQ\hat{j}$ (d) 0

163. A point charge 'q' sits at a corner of a cube of side 'a', as shown in the figure on the right. The flux of the electric field vector through the shaded side is

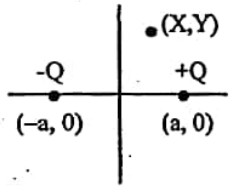


(a) $\frac{q}{8\varepsilon_0}$ (b) $\frac{q}{16\varepsilon_0}$ (c) $\frac{q}{24\varepsilon_0}$ (d) $\frac{q}{6\varepsilon_0}$

164. A parallel plate capacitor of circular cross section with radius r >>d, where 'd' is the spacing between the plates, is charged to a potential V and then disconnected from the charging circuit. If, now, the plates are slowly pulled apart (keeping then parallel) so that their separation is increased from d to d', the work done will be

(a) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\left(1-\frac{d}{d'}\right)$ (b) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\frac{d'}{d}$ (c) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\left(\frac{d'}{d}-1\right)$ (d) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\frac{d}{d'}$

165. Consider two charges +Q and –Q placed at the points (a, 0) and (–a, 0) in a plane, as shown in the figure on the right. If the origin is moved to the point (X, Y), the magnitude of the dipole moment of the given charge distribution with respect to this origin will be



(a) $Q\sqrt{(a-X)^2+y^2}-Q\sqrt{(a+X)^2+y^2}$ (b) $Q(a-X)-Q(-a+X)$

(c) $2Qa$ (d) $2Q\sqrt{X^2+Y^2}$

166. A plane electromagnetic wave travelling in a vacuum is characterised by the electric and magnetic fields

$$\vec{E}=\hat{i}\left(30\pi\ \mathrm{Vm^{-1}}\right)\exp i\left(\omega t+kz\right)$$

$$\vec{H}=\hat{j}\left(H_0\ \mathrm{Am^{-1}}\right)\exp i\left(\omega t+kz\right)$$

If $\omega, k>0$, the value of H_0 must be

(a) 2π (b) 0.67 (c) 0.25 (d) 0.94

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167. The magnetic vector potential $\vec{A}(\vec{r})$ corresponding to a uniform magnetic field $\vec{B}$ is taken in the form

$$\vec{A} = \frac{1}{2}\vec{B} \times \vec{r}$$

where '$\vec{r}$' is the position vector. If the electric field has the time dependent form $\vec{E} = \vec{E}_0(\vec{r})e^{i\omega t}$, where '$\omega$' is a constant, the gauge choice corresponding to this potential is a

(a) Lorenz gauge (b) Coulomb gauge (c) Non-linear gauge (d) Time-varying gauge.

168. Consider a hollow charged shell of inner radius 'a' and outer radius 'b'. The volume charge density is $\rho(r) = \frac{k}{r^2}$ (where k is a constant) in the region $a < r < b$. The magnitude of the electric field produced at distance $r > a$ is:

(a) $\frac{k(b-a)}{\varepsilon_0 r^2}$ for $r > a$

(b) $\frac{k(b-a)}{\varepsilon_0 r^2}$ for $a < r < b$ and $\frac{kb}{\varepsilon_0 r^2}$ for $r > b$

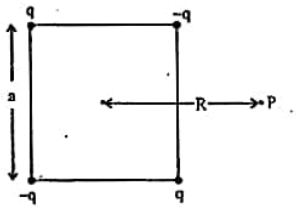
(c) $\frac{k(r-a)}{\varepsilon_0 r^2}$ for $a < r < b$ and $\frac{k(b-a)}{\varepsilon_0 r^2}$ for $r > b$

(d) $\frac{k(r-a)}{\varepsilon_0 a^2}$ for $a < r < b$ and $\frac{k(b-a)}{\varepsilon_0 a^2}$ for $r > b$

169. Consider the interference of two coherent electromagnetic waves whose electric field vectors are given by $\vec{E}_1 = \hat{i}E_0 \cos\omega t$ and $\vec{E}_2 = \hat{j}E_0 \cos(\omega t + \varphi)$ where φ is the phase difference. The intensity of the resulting wave is given by $\frac{\varepsilon_0}{2}\langle E^2 \rangle$, where $\langle E^2 \rangle$ is the time average of E^2. The total intensity is

(a) 0 (b) $\varepsilon_0 E_0^2$ (c) $\varepsilon_0 E_0^2 \sin^2\varphi$ (d) $\varepsilon_0 E_0^2 \cos^2\varphi$

170. Four charges (two +q and two –q) are kept fixed at the four vertices of a square of side 'a' as shown



At the point P which is at a distance R from the centre ($R >> a$), the potential is proportional to

(a) $\frac{1}{R}$ (b) $\frac{1}{R^2}$ (c) $\frac{1}{R^3}$ (d) $\frac{1}{R^4}$

171. A point charge 'q' of mass 'm' is kept at a distance 'd' below a grounded infinite conducting sheet which lies in the xy-plane. What is the value of 'd' for which the charge remains stationary?

(a) $q/4\sqrt{mg\pi\varepsilon_0}$ (b) $q/\sqrt{mg\pi\varepsilon_0}$

(c) There is no finite value of 'd' (d) $\sqrt{mg\pi\varepsilon_0}/q$

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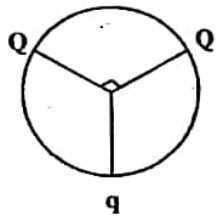
172. Three charges are located on the circumference of a circle of radius 'R' as shown in the figure below. The two charges Q subtend an angle 90° at the centre of the circle. The charge 'q' is symmetrically placed with respect to the charges Q. If the electric field at the centre of the circle is zero, what is the magnitude of Q?



(a) $q/\sqrt{2}$ (b) $\sqrt{2}q$ (c) $2q$ (d) $4q$

173. Consider an infinite conducting sheet in the xy-plane with a time dependent current density $Kt\hat{i}$, where K is a constant. The vector potential at (x, y, z) is given by

$$\bar{A} = \frac{\mu_0 K}{4c}(ct - z)^2 \hat{i}$$

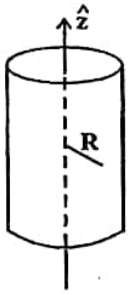
The magnetic field $\bar{B}$ is:

(a) $\frac{\mu_0 Kt}{2}\hat{j}$ (b) $-\frac{\mu_0 Kz}{2c}\hat{j}$ (c) $-\frac{\mu_0 K}{2c}(ct-z)\hat{i}$ (d) $-\frac{\mu_0 K}{2c}(ct-z)\hat{j}$

174. When a charged particle emits electromagnetic radiation, the electric field $\bar{E}$ and the Poynting vector $\bar{S} = \frac{1}{\mu_0}\bar{E}\times\bar{B}$ at a large distance 'r' from the emitter vary as $\frac{1}{r^n}$ and $\frac{1}{r^m}$ respectively. Which of the following choices for 'n' and 'm' are correct?

(a) n = 1 and m = 1 (b) n = 2 and m = 2 (c) n = 1 and m = 2 (d) n = 2 and m = 4

175. An infinite solenoid with its axis of symmetry along the z-direction carries a steady current I.



The vector potential $\bar{A}$ at a distance R from the axis.

(a) Is constant inside and varies as R outside the solenoid.
(b) Varies as R inside and is constant outside the solenoid.
(c) Varies as 1/R inside and as R outside the solenoid.
(d) Varies as R inside and as 1/R outside the solenoid.

176. At a surface current, which one of the magnetostatic boundary condition is NOT CORRECT?

(a) Normal component of the magnetic field is continuous.
(b) Normal component of the magnetic vector potential is continuous.
(c) Tangential component of the magnetic vector potential is continuous.
(d) Tangential component of the magnetic vector potential is not continuous.

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177. Interference fringes are seen at an observation plane $z=0$, by the superposition of two plane waves $A_1 \exp[i(\vec{k}_1 \cdot \vec{r} - \omega t)]$ and $A_2 \exp[i(\vec{k}_2 \cdot \vec{r} - \omega t)]$, where A_1 and A_2 are real amplitudes. The condition for interference maximum is

(a) $(\vec{k}_1 - \vec{k}_2)\cdot\vec{r} = (2m+1)\pi$ (b) $(\vec{k}_1 - \vec{k}_2)\cdot\vec{r} = 2m\pi$

(c) $(\vec{k}_1 + \vec{k}_2)\cdot\vec{r} = (2m+1)\pi$ (d) $(\vec{k}_1 + \vec{k}_2)\cdot\vec{r} = 2m\pi$

178. For a scalar function φ satisfying the Laplace equation, $\nabla\varphi$ has

(a) zero curl and non-zero divergence
(b) non-zero curl and zero divergence
(c) zero curl and zero divergence
(d) non-zero curl and non-zero divergence

179. A circularly polarized monochromatic plane wave is incident on a dielectric interface at Brewster angle. Which one of the following statements is CORRECT?

(a) The reflected light is plane polarized in the plane of incidence and the transmitted light is circularly polarized.
(b) The reflected light is plane polarized perpendicular to the plane of incidence and the transmitted light is plane polarized in the plane of incidence.
(c) The reflected light is plane polarized perpendicular to the plane of incidence and the transmitted light is elliptically polarized.
(d) There will be no reflected light and the transmitted light is circularly polarized.

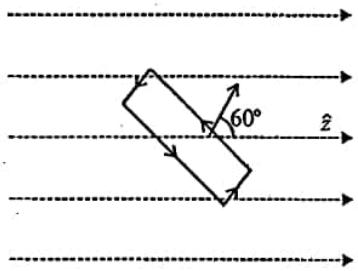
180. A charge distribution has the charge density given by $\rho = Q\{\delta(x-x_0) - \delta(x+x_0)\}$. For this charge distribution the electric field at $(2x_0, 0, 0)$

(a) $\dfrac{2Q\hat{x}}{9\pi\epsilon_0 x_0^2}$ (b) $\dfrac{Q\hat{x}}{4\pi\epsilon_0 x_0^3}$ (c) $\dfrac{Q\hat{x}}{4\pi\epsilon_0 x_0^2}$ (d) $\dfrac{Q\hat{x}}{16\pi\epsilon_0 x_0^2}$

181. A monochromatic plane wave at oblique incidence undergoes reflection at a dielectric interface. If $\hat{k}_i$, $\hat{k}_r$ and $\hat{n}$ are the unit vectors in the directions of incident wave, reflected wave and the normal to the surface respectively, which one of the following expression is correct?

(a) $(\hat{k}_i - \hat{k}_r)\times\hat{n} \neq 0$ (b) $(\hat{k}_i - \hat{k}_r)\cdot\hat{n} = 0$ (c) $(\hat{k}_i \times \hat{n})\cdot\hat{k}_r = 0$ (d) $(\hat{k}_i \times \hat{n})\cdot\hat{k}_r \neq 0$

182. In a constant magnetic field of 0.6 Tesla along the z direction, find the value of the path integral $\oint \vec{A}.d\vec{l}$ in the units of (Tesla m^2) on a square loop of side length $(1/\sqrt{2})$ meters. The normal to the loop makes an angle of 60° to the z-axis, as shown in he figure. The answer should be up to two decimal places. ____



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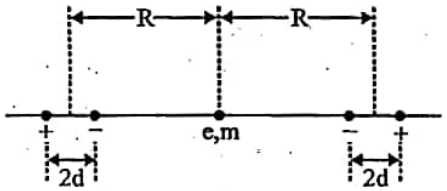
183. A particle of charge e and mass m is located at the midpoint of the line joining two mixed collinear dipoles with unit charges as shown in the figure. (The particle is constrained to move only along the line joining the dipoles). Assuming that the length of the dipoles is much shorter than their separation, the natural frequency of oscillation of the particle is



(1) $\sqrt{\frac{6e^2R^2}{\pi\varepsilon_0 md^5}}$ (2) $\sqrt{\frac{6e^2R}{\pi\varepsilon_0 md^4}}$ (3) $\sqrt{\frac{6e^2d^2}{\pi\varepsilon_0 mR^5}}$ (4) $\sqrt{\frac{6e^2d}{\pi\varepsilon_0 mR^4}}$

184. A current I is created by a narrow beam of protons moving in vacuum with constant velocity $\bar{u}$. The direction and magnitude, respectively, of the Poynting vector $\bar{S}$ outside the beam at a radial distance r (much larger than the width of the beam) from the axis, are

(1) $\bar{S}\perp\bar{u}$ and $|\bar{S}|=\frac{I^2}{4\pi^2\epsilon_0|\bar{u}|r^2}$ (2) $\bar{S}\parallel(-\bar{u})$ and $|\bar{S}|=\frac{I^2}{4\pi^2\epsilon_0|\bar{u}|r^4}$

(3) $\bar{S}\parallel\bar{u}$ and $|\bar{S}|=\frac{I^2}{4\pi^2\epsilon_0|\bar{u}|r^2}$ (4) $\bar{S}\parallel\bar{u}$ and $|\bar{S}|=\frac{I^2}{4\pi^2\epsilon_0|\bar{u}|r^4}$

185. If the electric and magnetic fields are unchanged when the vector potential $\bar{A}$ changes (in suitable units) according to $\bar{A}\rightarrow\bar{A}+\hat{r}$, where $\vec{r}=r(t)\hat{r}$, then the scalar potential Φ must simultaneously change to

(1) $\Phi - r$ (2) $\Phi + r$ (3) $\Phi - \partial r/\partial t$ (4) $\Phi + \partial r/\partial t$

186. Consider an axially symmetric static charge distribution of the form,

$\rho=\rho_0\left(\frac{r_0}{r}\right)^2 e^{-r/r_0}\cos^2\varphi$. The radial component of the dipole moment due to this charge distribution is

(1) $2\pi\rho_0 r_0^4$ (2) $\pi\rho_0 r_0^4$ (3) $\rho_0 r_0^4$ (4) $\pi\rho_0 r_0^4/2$

187. A uniform cylinder of radius r and length ℓ, and a uniform sphere of radius R are released on an inclined plane when their centres of mass are at the same height. If they roll down without slipping, and if the sphere reaches the bottom of the plane with a speed V, then the speed of the cylinder when it reaches the bottom is:

(1) $V\sqrt{\frac{14r\ell}{15R^2}}$ (2) $4V\sqrt{\frac{r}{15R}}$ (3) $\frac{4V}{\sqrt{15}}$ (4) $V\sqrt{\frac{14}{15}}$

188. The components of a vector potential $A_\mu\equiv(A_0,A_1,A_2,A_3)$ are given by $A_\mu=k(-xyz,yzt,zxt,xyt)$ where k is a constant. The three components of the electric field are

(1) k(yz, zx, xy) (2) k(x, y, z) (3) (0, 0, 0) (4) k(xt, yt, zt)

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189. An oscillating current $I(t) = I_0 \exp(-i\omega t)$ flows in the direction of the y-axis through a thin metal sheet of area 1.0 cm^2 kept in the xy-plane. The rate of total energy radiated per unit area from the surfaces of the metal sheet at a distance of 100m is

(1) $I_0\omega/(12\pi\varepsilon_0 c^3)$ (2) $I_0^2\omega^2/(12\pi\varepsilon_0 c^3)$

(3) $I_0^2\omega/(12\pi\varepsilon_0 c^3)$ (4) $I_0\omega^2/(24\pi\varepsilon_0 c^3)$

190. The motion of an electron in an electromagnetic field is governed by

(a) Coulomb Force law (b) Gauss' Law (c) Lenz's law (d) Lorentz force law

191. For the magnetic field measurement, Gauss-meters employ the principle of

(a) double exchange (b) super exchange (c) Jahn-Teller effect (d) Hall effect

192. Which one of the following is not correct?

(a) $\nabla\cdot(\nabla\phi) = \nabla^2\phi$ (b) $\nabla\times(\nabla\times A) = \nabla(\nabla\cdot A) - \nabla^2 A$

(c) $\nabla\cdot(\nabla\times A) = 0$ (d) $\nabla\times(\nabla\phi) = \phi$

193. For a transparent material the ratio of reflected intensity to the incident intensity depends on

(a) its absorption coefficient

(b) its refractive index only

(c) its absorption coefficient and transmission coefficients

(d) its high transmission coefficient

194. The electric fields outside ($r > R$) and inside ($r < R$) a solid sphere with a uniform volume charge density are given by $\vec{E}_{r>R} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$ and $\vec{E}_{r<R} = \frac{1}{4\pi\epsilon_0}\frac{q}{R^3}r\hat{r}$ respectively, while the electric field outside a spherical shell with a uniform surface charge density is given by $\vec{E}_{r>R} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$, q being the total charge. The correct ratio of the electrostatic energies for the second case to the first case is

(a) 1:3 (b) 9:16 (c) 3:8 (d) 5:6

195. The vector field $xz\hat{i} + y\hat{j}$ in cylindrical polar coordinates is

(a) $\rho(z\cos^2\phi + \sin^2\phi)\hat{e}_\rho + \rho\sin\phi\cos\phi(1-z)\hat{e}_\phi$ (b) $\rho(z\cos^2\phi + \sin^2\phi)\hat{e}_\rho + \rho\sin\phi\cos\phi(1+z)\hat{e}_\phi$

(c) $\rho(z\sin^2\phi + \cos^2\phi)\hat{e}_\rho + \rho\sin\phi\cos\phi(1+z)\hat{e}_\phi$ (d) $\rho(z\sin^2\phi + \cos^2\phi)\hat{e}_\rho + \rho\sin\phi\cos\phi(1-z)\hat{e}_\phi$

196. At 'equilibrium' there can not be any free charge inside a metal. However, if you forcibly put charge in the interior then it takes some finite time to 'disappear', *i.e.* move to the surface. If the conductivity, σ, of a metal is $10^6(\Omega m)^{-1}$ and the dielectric constant $\epsilon_0 = 8.85\times10^{-12}$ Farad/m, this time will be approximately:

(a) 10^{-5} sec (b) 10^{-11} sec (c) 10^{-9} sec (d) 10^{-17} sec

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197. An electromagnetic wave of frequency ω travels in the x-direction through vacuum. It is polarized in the y-direction and the amplitude of the electric field is E_0. With $k = \omega/c$ where c is the speed of light in vacuum, the electric and the magnetic fields are then conventionally given by

(a) $\vec{E} = E_0 \cos(ky - \omega t)\hat{x}$ and $\vec{B} = \frac{E_0}{c}\cos(ky - \omega t)\hat{z}$

(b) $\vec{E} = E_0 \cos(kx - \omega t)\hat{y}$ and $\vec{B} = \frac{E_0}{c}\cos(kx - \omega t)\hat{z}$

(c) $\vec{E} = E_0 \cos(kx - \omega t)\hat{z}$ and $\vec{B} = \frac{E_0}{c}\cos(kx - \omega t)\hat{y}$

(d) $\vec{E} = E_0 \cos(kx - \omega t)\hat{x}$ and $\vec{B} = \frac{E_0}{c}\cos(ky - \omega t)\hat{y}$

198. If $\vec{E}_1 = xy\hat{i} + 2yz\hat{j} + 3xz\hat{k}$ and $\vec{E}_2 = y^2\hat{i} + (2xy + z^2)\hat{j} + 2yz\hat{k}$ then

(a) Both are impossible electrostatic fields.
(b) Both are possible electrostatic fields.
(c) Only $\vec{E}_1$ is a possible electrostatic field.
(d) Only $\vec{E}_2$ is a possible electrostatic field.

199. A charge q is placed at the centre of an otherwise neutral dielectric sphere of radius a and relative permittivity ϵ_r. We denote the expression $q/4\pi\epsilon_0 r^2$ by $E(r)$. Which of the following statements is false?

(a) The electric field inside the sphere, $r < a$, is given by $E(r)/\epsilon_r$.
(b) The field outside the sphere, $r > a$, is given by $E(r)$.
(c) The total charge inside a sphere of radius $r > a$ is given by q.
(d) The total charge inside a sphere of radius $r < a$ is given by q.

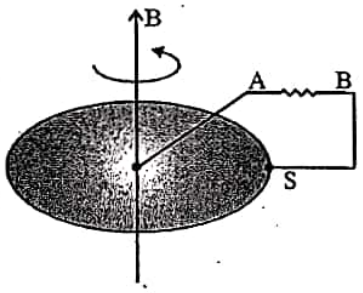
200. The electric and magnetic fields caused by an accelerated charged particle are found to scale as $E \propto r^{-n}$ and $B \propto r^{-m}$ at large distances. What are the values of n and m?

(a) $n = 1, m = 2$ (b) $n = 2, m = 1$ (c) $n = 1, m = 1$ (d) $n = 2, m = 2$

201. The conductors in a 0.75 km long two-wire transmission line are separated by a centre-to-centre distance of 0.2m. If each conductor has a diameter of 4cm, then the capacitance of the line is

(a) 8.85 μF (b) 88.5 nF (c) 8.85 pF (d) 8.85 nF

202. A horizontal metal disc rotates about the vertical axis in a uniform magnetic field pointing up as shown in the figure. A circuit is made by connecting one end A of a resistor to the centre of the disc and the other end B to its edge through a sliding contact S. The current that flows through the resistor is



(a) zero
(b) DC from A to B
(c) DC from B to A
(d) AC

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203. The force between two long and parallel wires carrying currents I_1 and I_2 and separated by a distance D is proportional to

(a) $I_1 I_2 / D$ (b) $(I_1 + I_2) / D$ (c) $(I_1 I_2 / D)^2$ (d) $I_1 I_2 / D^2$

204. Let (V, A) and (V', A') denote two sets of scalar and vector potentials, and ψ a scalar function. Which of the following transformations leave the electric and magnetic fields (and hence Maxwell's equations) unchanged?

(a) $A' = A + \nabla\psi$ and $V = V - \frac{\partial\psi}{\partial t}$ (b) $A' = A - \nabla\psi$ and $V' = V + 2\frac{\partial\psi}{\partial t}$

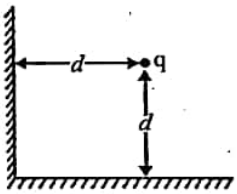
(c) $A' = A + \nabla\psi$ and $V' = V + \frac{\partial\psi}{\partial t}$ (d) $A' = A - 2\nabla\psi$ and $V' = V - \frac{\partial\psi}{\partial t}$

205. The electric field of an electromagnetic wave is given by $\vec{E} = E_0 \cos[\pi(0.3x + 0.4y - 1000t)]\hat{k}$. The associated magnetic field $\vec{B}$ is

(a) $10^{-3} E_0 \cos[\pi(0.3x + 0.4y - 1000t)]\hat{k}$ (b) $10^{-4} E_0 \cos[\pi(0.3x + 0.4y - 1000t)](4\hat{i} - 3\hat{j})$

(c) $E_0 \cos[\pi(0.3x + 0.4y - 1000t)](0.3\hat{i} + 0.4\hat{j})$ (d) $10^2 E_0 \cos[\pi(0.3x + 0.4y - 1000t)](3\hat{i} + 4\hat{j})$

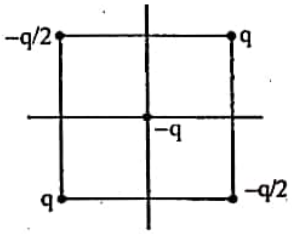
206. A point charge q is placed symmetrically at a distance d from two perpendicularly placed grounded conducting infinite plates as shown in the figure. The net force on the charge (in units of $1/4\pi\epsilon_0$) is



(a) $\frac{q^2}{8d^2}(2\sqrt{2} - 1)$ away from the corner (b) $\frac{q^2}{8d^2}(2\sqrt{2} - 1)$ towards the corner

(c) $\frac{q^2}{2\sqrt{2}d^2}$ towards the corner (d) $\frac{3q^2}{8d^2}$ away from the corner

207. Let four point charges q, –q/2, q and –q/2 be placed at the vertices of a square of side a. Let another point charge –q be placed at the centre of the square (see the figure).



Let $V(r)$ be the electrostatic potential at a point P at a distance $r >> a$ from the centre of the square. Then $V(2r) / V(r)$ is

(a) 1 (b) $\frac{1}{2}$ (c) $\frac{1}{4}$ (d) $\frac{1}{8}$

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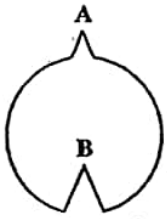
208. If the electrostatic potential $V(r,\theta,\phi)$ in a charge free region has the form $V(r,\theta,\phi) = f(r)\cos\theta$, then the functional form of $f(r)$ (in the following a and b are constants) is

(a) $ar^2 + \frac{b}{r}$ (b) $ar + \frac{b}{r^2}$ (c) $ar + \frac{b}{r}$ (d) $a\ln\left(\frac{r}{b}\right)$

209. A solid spherical conductor has a conical hole made at one end, ending in a point B, and a small conical projection of the same shape and size at the opposite side, ending in a point A. A cross-section through the centre of the conductor is shown in the figure on the right.



If now, a positive charge Q is transferred to the sphere, then

(a) The charge density at both A and B will be undefined.

(b) The charge density at A will be the same as the charge density at B.

(c) The charge density at A will be more than the charge density at B.

(d) The charge density at B will be more than the charge density at A.

210. Solving Poisson's equation $\nabla^2\varphi = -\rho_0/\varepsilon_0$ for the electrostatic potential $\varphi(\vec{x})$ in a region with a constant charge density ρ_0, two students find different answers, viz,

$$\varphi_1(\vec{x}) = -\frac{1}{2}\frac{\rho_0 x^2}{\varepsilon_0} \text{ and } \varphi_2(\vec{x}) = -\frac{1}{2}\rho_0 y^2 \varepsilon_0$$

The reason why these different solutions are both correct is because

(a) space is isotropic and hence x and y are physically equivalent.

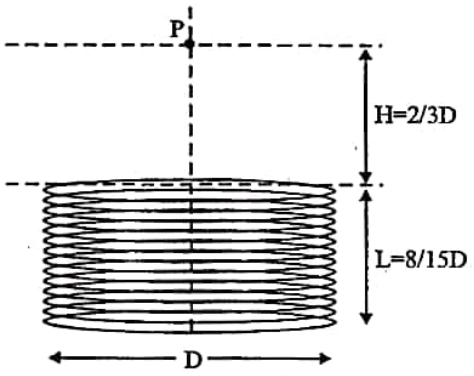
(b) We can add solutions of Laplace's equation to both $\varphi_1(\vec{x})$ and $\varphi_2(\vec{x})$

(c) The electrostatic energy is infinite for a constant charge density.

(d) The boundary conditions are different in the two cases.

211. A short solenoid with n turns per unit length has diameter D and length L = 8D/15, as shown in the figure, and it carries a constant current I. The magnetic field B at a point P on the axis of the solenoid at a distance H = 2D/3 from its near end (see figure) is

[use $\int dx\left(1+x^2\right)^{-3/2} = x\left(1+x^2\right)^{-1/2}$]



(a) $\frac{4}{65}\mu_0 nI$ (b) $\frac{4}{13}\mu_0 nI$ (c) $\frac{24}{15}\mu_0 nI$ (d) $\frac{112}{65}\mu_0 nI$

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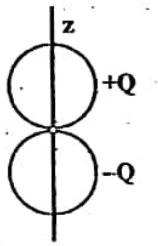
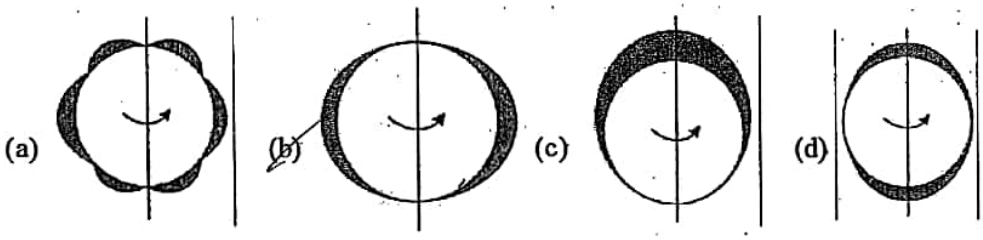
212. An electric dipole is constructed by fixing two circular charged rings, each of radius 'a', with an insulating contact (see figure). One of these rings has total charge +Q and the other has total charge −Q. If the charge is distributed uniformly along each ring, the dipole moment about the point of contact will be



(a) $\frac{Qa}{\pi}\hat{z}$ (b) $4\pi Qa\hat{z}$ (c) $2Qa\,\hat{z}$ (d) Zero

213. A spherical conductor, carrying a total charge Q, spins uniformly and very rapidly about an axis coinciding with one of its diamters. In the diagrams given below, the equilibrium charge density on its surface is represented by the thickness of the shaded region. Which of these diagram is correct?



214. The instantaneous electric and magnetic fields created at a distance 'r' by a point source at the origin are given by

$$\vec{E}=\frac{A\cos\omega t}{2\pi\varepsilon_0 r}\hat{\theta} \qquad \hat{H}=\frac{B\cos\omega t}{\mu_0 r}\hat{\varphi}$$

where ω, A, B are constants, and the unit vectors $(\hat{r},\hat{\theta},\hat{\varphi})$ form an orthonormal set. The time-averaged power radiated by the source is

(a) $\frac{\omega\varepsilon_0}{\mu_0}AB$ (b) $\frac{c^3}{2\pi}AB$ (c) c^2AB (d) $\frac{2\pi\omega}{c}AB$

215. A thin uniform ring carrying charge Q and mass M rotates about its axis. What is the gyromagnetic ratio (defined as ratio of magnetic dipole moment to the angular momentum) of this ring?

(a) $Q/(2\pi M)$ (b) Q/M (c) $Q/(2M)$ (d) $Q/(\pi M)$

216. A charged particle is at a distance d from an infinite conducting plane maintained at zero potential. When released from rest, the particle reaches a speed u at a distance d/2 from the plane. At what distance from the plane will the particle reach the speed 2u?

(a) d/6 (b) d/3 (c) d/4 (d) d/5

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217. Consider an electromagnetic wave at the interface between two homogeneouos dielectric media of the dielectric constants ε_1 and ε_2. Assuming $\varepsilon_2 > \varepsilon_1$ and non charges on the surface, the electric field vector E and the displacement vector $\vec{D}$ in the two media satisfy the following inequalities

(a) $|\vec{E}_2| > |\vec{E}_1|$ and $|\vec{D}_2| > |\vec{D}_1|$ (b) $|\vec{E}_2| < |\vec{E}_1|$ and $|\vec{D}_2| < |\vec{D}_1|$

(c) $|\vec{E}_2| < |\vec{E}_1|$ and $|\vec{D}_2| > |\vec{D}_1|$ (d) $|\vec{E}_2| > |\vec{E}_1|$ and $|\vec{D}_2| < |\vec{D}_1|$

218. If the electrostatic potential in spherical polar coordinates is

$$\varphi(r) = \varphi_0 e^{-r/r_0}$$

where φ_0 and r_0 are constants, then the charge density at a distance $r = r_0$ will be

(a) $\frac{\varepsilon_0 \varphi_0}{e r_0^2}$ (b) $\frac{\varepsilon \varepsilon_0 \varphi_0}{2 r_0^2}$ (c) $-\frac{\varepsilon_0 \varphi_0}{e r_0^2}$ (d) $-\frac{2\varepsilon \varepsilon_0 \varphi_0}{r_0^2}$

219. A time-dependent current $\bar{I}(t) = Kt\hat{z}$ (where K is a constant) is switched on at t = 0 in an infinite current-carrying wire. The magnetic vector potential at a perpendicular distance 'a' from the wire is given (for time $t > a/c$) by

(a) $\hat{z}\frac{\mu_0 K}{4\pi c}\int_{-\sqrt{c^2t^2-a^2}}^{\sqrt{c^2t^2-a^2}} dz \frac{ct-\sqrt{a^2+z^2}}{\left(a^2+z^2\right)^{1/2}}$ (b) $\hat{z}\frac{\mu_0 K}{4\pi}\int_{-ct}^{ct} dz \frac{ct-\sqrt{a^2+z^2}}{\left(a^2+z^2\right)^{1/2}}$

(c) $\hat{z}\frac{\mu_0 K}{4\pi c}\int_{-ct}^{ct} dz \frac{ct-\sqrt{a^2+z^2}}{\left(a^2+z^2\right)^{1/2}}$ (d) $\hat{z}\frac{\mu_0 K}{4\pi}\int_{-\sqrt{c^2t^2-a^2}}^{\sqrt{c^2t^2-a^2}} dz \frac{t}{\left(a^2+z^2\right)^{1/2}}$

220. A doubel slit interference experiment uses a laser emitting light of two adjacent frequencies ν_1 and ν_2 $(\nu_1 < \nu_2)$. The minimum path difference between the interfering beams for which the interference pattern disappears is

(a) $\frac{c}{\nu_2+\nu_1}$ (b) $\frac{c}{\nu_2-\nu_1}$ (c) $\frac{c}{2(\nu_2-\nu_1)}$ (d) $\frac{c}{2(\nu_2+\nu_1)}$

221. A charge (–e) is placed in vacuum at the point (d, 0, 0), where d > 0. The region $x \le 0$ is filled uniformly with a metal. The electric field at the point $\left(\frac{d}{2}, 0, 0\right)$ is

(a) $-\frac{10e}{9\pi\varepsilon_0 d^2}(1,0,0)$ (b) $\frac{10e}{9\pi\varepsilon_0 d^2}(1,0,0)$ (c) $\frac{e}{\pi\varepsilon_0 d^2}(1,0,0)$ (d) $-\frac{e}{\pi\varepsilon_0 d^2}(1,0,0)$

222. A beam of light of frequency ω is reflected from a dielectric-metal interface at normal incience. the refractive index of the dielectric medium is n and that of the metal is $n_2 = n(1+i\rho)$. If the beam is polarised parallel to the interface, then the phase change experienced by the light upon reflection is

(a) $\tan\left(\frac{2}{\rho}\right)$ (b) $\tan^{-1}\left(\frac{1}{\rho}\right)$ (c) $\tan^{-1}\left(\frac{2}{\rho}\right)$ (d) $\tan^{-1}(2\rho)$

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223. A thin infinitely long solenoid placed along the z-axis contains a magnetic flux ϕ. Which of the following vector potentials corresponds to the magnetic field at an arbitrary point (x,y,z)?

(a) $(A_x,A_y,A_z)=\left(-\frac{\phi}{2\pi}\frac{y}{x^2+y^2},\frac{\phi}{2\pi},\frac{x}{x^2+y^2},0\right)$

(b) $(A_x,A_y,A_z)=\left(-\frac{\phi}{2\pi}\frac{y}{x^2+y^2+z^2},\frac{\phi}{2\pi},\frac{x}{x^2+y^2+z^2},0\right)$

(c) $(A_x,A_y,A_z)=\left(-\frac{\phi}{2\pi}\frac{x+y}{x^2+y^2},\frac{\phi}{2\pi},\frac{x}{x^2+y^2},0\right)$

(d) $(A_x,A_y,A_z)=\left(-\frac{\phi}{2\pi}\frac{x}{x^2+y^2},\frac{\phi}{2\pi},\frac{y}{x^2+y^2},0\right)$

224. An electromagnetically-shielded room is designed so that at a frequency $\omega=10^7$ rad/s the intensity of the external radiation that penerates the room is 1% of the incident radiation. If $\sigma=\frac{1}{2\pi}\times10^6\,(\Omega m)^{-1}$ is the conductivity of the shielding material, its minimum thickness should be (given that in 10 = 2.3)

(a) 4.60 mm (b) 2.30 mm (c) 0.23 mm (d) 0.46 mm

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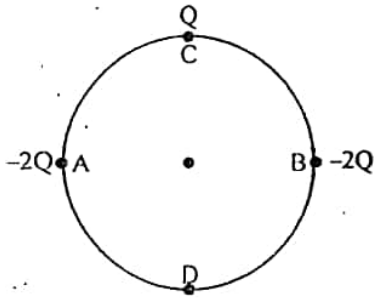
PHYSICAL SCIENCES

Assignment-01: Electromagnetic Theory

1. Three point charges are placed on the circumference of a circle as shown in the figure. What charge should be placed at D so that net force on C becomes zero?



2. Calculate total charge in the following cases.

(i) A infinitely long line charge lying along z axis has linear charge density $\lambda(z) = \frac{\lambda_0}{1+z^2}$

(ii) A circular disc of radius R has surface charge density $\sigma(r,\theta) = \sigma_0 r^2 \sin^2\theta$

(iii) A solid sphere of radius R has volume charge density $\rho = \vec{a}\cdot\vec{r}$, where $\vec{a}$ is a constant vector and $\vec{r}$ is radial vector.

(iv) A spherical shell of radius R has surface charge density $\sigma(\theta) = \sigma_0 \cos^2\theta$

3. Find the electric field at (0, 3, 4)m due to a point charge $q = 1\mu C$ at (1, 1, 1).

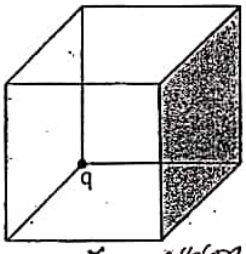
4. Two point charges $q_1 = 10\mu C$ and $q_2 = 50\mu C$ are located at (–1, 1, –3)m and (3, 1, 0)m, respectively. Find the force on a point charge $q_3 = 1\mu C$ placed at the origin.

5. Find the force on a point charge of $50\mu C$ at (0, 0, 5)m due to the charge $500\pi\mu C$ uniformly distributed over a circular disk of radius r = 5m placed at z = 0.

6. Charge lies in the $z = -3m$ plane in the form of a square sheet defined by $-2 \le x \le 2m$, $-2 \le y \le 2m$ with surface charge density $\sigma = 2(x^2 + y^2 + 9)^{3/2} nC/m^2$. Find $\vec{E}$ field at the origin.

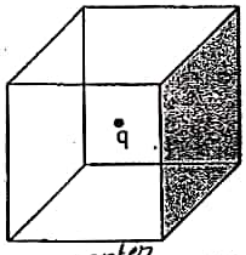
7. Calculate the flux of $\vec{E}$ through the shaded side?

(i)



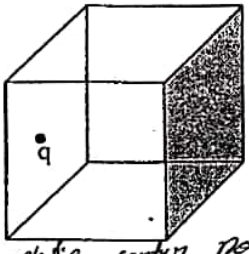
corner position

(ii)



center position

(iii)



phase center position

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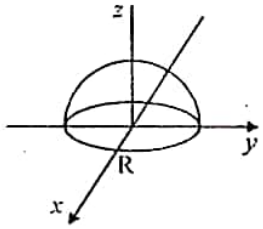
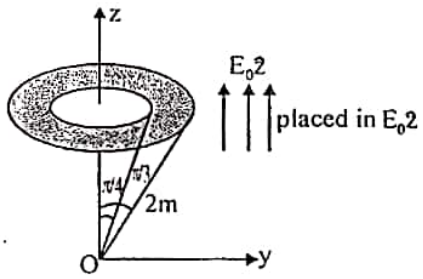
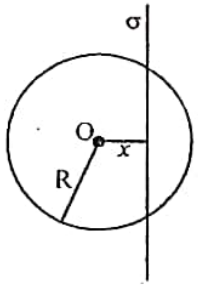
8. A closed hemispherical bowl as shown in the figure, is placed in an electric field given by $\vec{E} = (r\cos\theta)\hat{r} + (r\sin\theta)\hat{\theta} + (r\sin\theta\cos\phi)\hat{\phi}$. Calculate the electric flux passing through the hemisphere.



9. (i) Calculate the electric flux through the following surface:

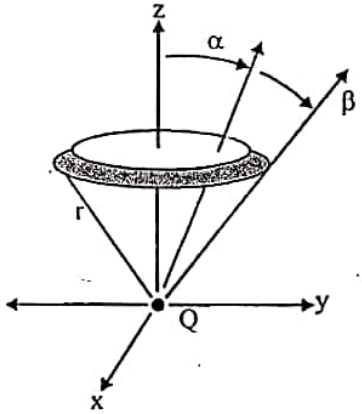


(ii) A plane sheet of surface charge density σ is inserted into a sphere of radius R. The perpendicular distance of the plane from the centre is x. Calculate the flux passing through the sphere.



10. Electric field in space is given to be $\vec{E} = \alpha r\cos^2\theta\hat{r} + \alpha r\sin^2\theta\hat{\phi}$ where r, θ and ϕ are spherical polar coordinates. Calculate total charge enclosed by a sphere of radius R centered at origin.

11. A point charge Q is at the origin of a spherical coordinates system. Find the flux which crosses the portion of a spherical shell described by $\alpha \le \theta \le \beta$ (Fig.). What is the result if $\alpha = 0$ and $\beta = \pi/2$?



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12. Given that $\bar{E} = 2r\cos\phi\hat{\phi} - \frac{\sin\phi}{3r}\hat{z}$ in cylindrical coordinates, find the flux crossing the portion of the $z = 0$ plane defined by $r \le a$, $0 \le \phi \le \pi/2$. Repeat for $3\pi/2 \le \phi \le 2\pi$. Assume flux positive in the $\hat{z}$ direction.

13. Suppose the electric field in some region is found to be $\bar{E} = kr^3\hat{r}$, in spherical coordinates (k is some constant).
(i) Find the charge density ρ.
(ii) Find the total charge contained in a sphere of radius R, centered at the origin.

14. Find the charge enclosed in the cylindrical volume $1 \le r \le 3m$, $0 \le \phi \le \pi/3$, $0 \le z \le 2m$ given the charge density $\rho = 2z\sin^2\phi(C/m^3)$.

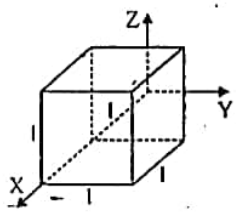
15. Electric field in a region is given to be $\bar{E} = \frac{1}{r}(\alpha\hat{r} + \beta\sin\theta\cos\phi\hat{\phi})$, calculate:
(i) The electric flux passing through a sphere of radius R centered at the origin.
(ii) Charge density ρ corresponding to this electric field.
(iii) Total charge enclosed by the sphere.

16. Given that $\bar{E} = z s\cos^2\phi\hat{z}$ N/c. Calculate the charge density at $(1, \pi/4, 3)$ and the total charge enclosed by the cylinder of radius 1m with $-2 \le z \le 2m$.

17. If $\bar{E} = (2y^2 + z)\hat{x} + 4xy\hat{y} + x\hat{z}$ N/c, find
(a) The volume charge density at $(-1, 0, 3)$
(b) The flux through the cube defined by $0 \le x \le 1, 0 \le y \le 1, 0 \le z \le 1$
(c) The total charge enclosed by the cube

18. If the electric flux density is $\bar{E} = \frac{10}{r}\hat{r}$ N/c, find the total charge within the sphere of radius 2m.

19. For the electric field $\bar{E} = (kx^{1/2})\hat{x}$ where k is a constant, compute the net electric flux through the cubic as shown in figure. What is the charge contained in the cube?



20. Given a charge density in spherical coordinates $\rho = \frac{\rho_0}{(r/r_0)^2}e^{-r/r_0}\cos^2\phi$ find the amounts of charge in the spherical volumes enclosed by $r = r_0$ and $r = \infty$.

21. Find the net charge enclosed in a cube of side 2m, parallel to the axes and centered at the origin, if the charge density is $\rho = 50x^2\cos\left(\frac{\pi}{2}y\right)(\mu C/m^3)$.

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22. A charge configuration in ~~cylindrical~~ coordinates is given by $\rho = 5re^{-2r}\ (C/m^3)$. Find

(i) electric field $(\vec{E})$ (ii) total charge in the whole space

23. The electric field in some region is given by $\vec{E}(r) = \frac{A}{r}\hat{r} + \frac{B\sin\theta\cos\phi}{r}\hat{\phi}$. Find

(i) charge density $\rho(r)$ in space

(ii) total charge in the sphere of radius R centered at the origin.

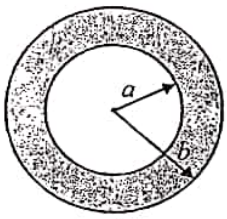
(iii) component of dipole moment in radial direction.

24. Find the electric field inside and outside a uniformly charged solid sphere of radius R and total charge q.

25. A long cylinder carries a charge density that is proportional to the distance from the axis: $\rho = ks$, for some constant k. Find the electric field inside this cylinder.

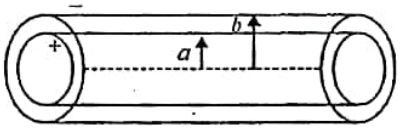
26. Find the electric field a distance s from an infinity long straight wire, which carries a uniform line charge λ.

27. A hollow spherical shell carries charge density $\rho = \frac{k}{r^2}$ in the region $a \le r \le b$ (fig.). Find the electric field in the three regions (i) $r < a$ (ii) $a < r < b$, (iii) $r > b$. Also find total charge on the spherical shell.



28. An infinite plane carries a uniform surface charge σ. Find its electric field.

29. A long coaxial cable (Fig.) carries a uniform volume charge density ρ on the inner cylinder (radius a), and a uniform surface charge density on the outer cylindrical shell (radius b). This surface charge is negative and of just the right magnitude so that the cable as a whole is electrically natural. Find the electric field in each of the three regions: (i) inside the inner cylinder ($s < a$), (ii) between the cylinders ($a < s < b$), (iii) outside the cable ($s > b$).



30. A spherical charge distribution is given by

$\rho = \rho_0\left(1 - \frac{r^2}{a^2}\right)$ for $r \le a$,

$\rho = 0$ for $r > a$

where a is the sphere. Find electric field intensity at a distance r from the centre when $r > a$ and when $r < a$. Find the value of r at which electric field is maximum.

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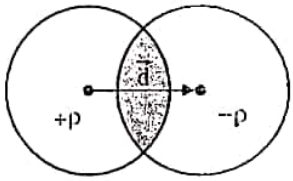
31. Imagine overlapping of two solid spheres of same radii and carrying uniform volume charges of densities ρ and $-\rho$. Calculate electric field in the overlapping region if distance between their centers is d.



32. A total charge Q is distributed in the volume of a solid sphere of radius R such that density of the charge is $\rho = kd$ where k is constant and d is depth from surface. Find value of k and also find value of electric field at depth d. At what value of d field is maximum.

33. Charge density on the surface of a hemisphere is $\sigma = \sigma_0 \cos\theta$, if the radius of the hemisphere is R then find the electric field at this centre of the hemisphere.

34. A sphere of radius R contains space charge density $\rho(r) = A(R-r)$ for $0 < r < R$. The total electric charge inside the sphere is Q.
(a) Express A in terms of Q and R
(b) Find the electric field inside and outside the sphere

35. The electric field in a region is given to be $\vec{E} = ay\hat{i} + bx\hat{j} + cy\hat{k}$. Calculate the values of constants a, b and c, so that $\vec{E}$ is electrostatic field.

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PHYSICAL SCIENCES

Assignment-02: Electromagnetic Theory

1. Find out which electric field is electrostatic?

   (a) $\vec{E} = k[xy\hat{x} + 2yz\hat{y} + 3xz\hat{z}]$; (b) $\vec{E} = k[y^2\hat{x} + (2xy + z^2)\hat{y} + 2yz\hat{z}]$

2. Compute the rotor (curl) and divergence of the electric field given by $\vec{E}(x,y,z) = (x^2 + z^2 + 5)\hat{x} + (y^2 + x^2 - 93)\hat{y} + (z^2 + y^2)\hat{z}$. Is this field irrotational (conservative, electrostatic).

3. Determine which of the following are genuine electric fields (Electrostatic fields)

   (a) $\vec{E}_1 = 5x^3\hat{x} + 15x^2y\hat{y}$ (b) $\vec{E}_2 = 2s(z+1)\sin\phi\hat{s} + s(z+1)\cos\phi\hat{\phi} + \hat{s}\sin\phi\hat{z}$

   (c) $\vec{E}_3 = \frac{5}{r}\sin\theta\cos\phi\,\hat{r}$

4. Determine the electric field due to the following potentials:

   (a) $V = x^2 + 2y^2 + 4z^2$ (b) $V = \sin(x^2 + y^2 + z^2)^{1/2}$

   (c) $V = r^2(z + 1)\sin\phi$ (d) $V = e^{-r}\sin\theta\cos 2\phi$

5. Find the potential inside and outside a spherical shell of radius R which carries a uniform surface charge σ.

6. Find the potential inside and outside a uniformly charged solid sphere whose radius is R and whose total charge is q. Compute the gradient of V in each region, and check that it yields the correct electric field.

7. Find the potential a distance s from an infinitely long straight wire that carries a uniform line charge λ. Compute the gradient of your potential, and check that it yields the correct field.

8. For a spherical charge distribution

$$\rho = \begin{cases} \rho_0(a^2 - r^2), & r < a \\ 0, & r > a \end{cases}$$. Find

   (a) E and V for $r \geq a$ (b) E and V for $r \leq a$

   (c) The total charge within the sphere (d) The value of r at which E is maximum.

9. The electric potential of some configuration is given by the expression $V(r) = A\frac{e^{-\lambda r}}{r}$, where A and λ are constants. Find the electric field $\vec{E}(r)$, the charge density $\rho(r)$, and the total charge Q.

10. Given the potential $V = \frac{10}{r^2}\sin\theta\cos\phi$ in spherical polar coordinate system.

    (a) Find the electric flux density $\vec{E}$ at $(2, \pi/2, 0)$.

    (b) Calculate the work done in moving a $10\mu C$ charge from point A(1, 30°, 120°) to B(4, 90°, 60°).

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11. The potential of the spherical charge distribution is given by

$$V(r,\theta,\phi)=\left(\frac{V_0}{2}\right)\left(3-\frac{r^2}{R^2}\right) \quad r<R$$

$$=\frac{V_0 R}{r} \quad r>R$$

where V_0 and R are constants.
(a) Obtain the corresponding electric field distribution
(b) To what charge distribution would this correspond.
(c) Total charge on the sphere.

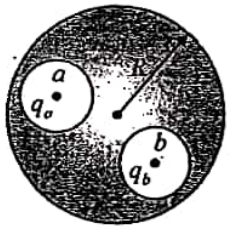
12. Determine the potential difference in volts between the points A(2, 0, –3) and B(1, $\frac{\pi}{2}$, 7) lying in a region having electric field intensity $\bar{E}=\frac{\cos\phi}{s^2}\hat{s}+\frac{\sin\phi}{s^2}\hat{\phi}$ V/m.

13. Given that $\bar{E}=(3x^2+y)\hat{x}+x\hat{y}$ kV/m, find the work done in moving a –2μC charge from (0, 5, 0) to (2, –1, 0) by taking the straight line path.

14. Given that the electric field in a certain region is $\bar{E}=(z+1)\sin\phi\,\hat{s}+(z+1)s\cos\phi\,\hat{\phi}+s\sin\phi\,\hat{z}$ V/m determine the work done in moving a 4nC charge from
(a) A(1, 0, 0) to B(4, 0, 0) (b) B(4, 0, 0) to C(4, 30°, 0)

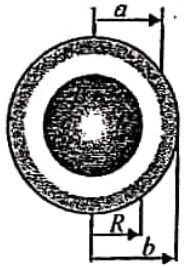
15. If $V=s^2z\sin\phi$, calculate the energy stored within the region defined by $1<s<4, -2<z<2, 0<\phi<\pi/3$.

16. Two spherical cavities, of radii *a* and *b*, are hollowed out from the interior of a (neutral) conducting sphere of radius *R* shown in figure. At the centre of each cavity a point charge is placed - call these charges q_a and q_b.



(a) Find the surface charges σ_a, σ_b and σ_R
(b) What is the field outside the conductor?
(c) What is the field within each cavity?
(d) What is the force on q_a and q_b?
(e) Which of these answers would change if a third charge, q_c, were brought near the conductor?

17. A metal sphere of radius *R*, carrying charge *q*, is surrounded by a thick concentric metal shell (inner radius *a*, outer radius *b*, as shown in figure). The shell carries no net charge.



(a) Find the surface charge density σ at *R*, at *a*, and at *b*.
(b) Find the potential at the center, using infinity as the reference point.
(c) Now the outer surface is touched to a grounding wire, which lowers its potential to zero (same as at infinity).
How do your answers to (a) and (b) change?

18. The force on a particle of charge $q = 2$ coulomb in an electrostatic field is given by $\bar{F}=A(yz\hat{i}+zx\hat{j}+xy\hat{k})$ where A = 10 Nm^{-2}. If the corresponding potential at the origin of coordinates is 10V, calculate the potential at the point $x=2, y=1, z=3$.

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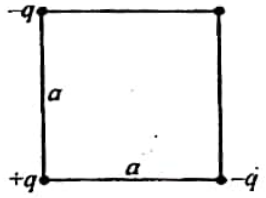
19. Two conducting spheres of charges Q_1 and Q_2 and radius r_1 and r_2 respectively, such that $(r_1 > r_2)$, now these two conductors are connected by a metallic wire. Calculate the potential and charge on two spheres after connection.

20. (a) Three charges are situated at the corners of a square (side a), as shown in figure. How much work does it take to bring in another charge, $+q$, from far away and place it in the fourth corner?
(b) How much work does it take to assemble the whole configuration of four charges?

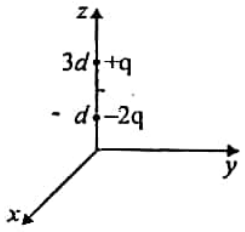


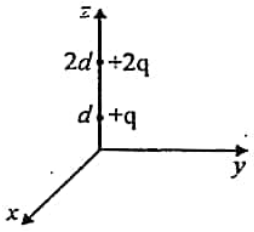
21. Calculate the workdone in assembling the charge configuration containing three points charges +q, −q and +q at the vertices of an equilateral triangle with side a.

22. Find the energy of a uniformly charged spherical shell of total charge q and radius R.

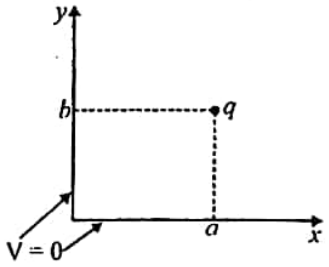
23. A sphere of radius R carries a charge density $\rho(r) = kr$ (where k is a constant). Find the energy of this charge configuration.

24. Find the force on the charge $+q$ in figure. (The xy plane is a grounded conductor).

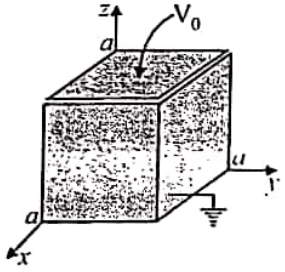
(a)


(b)


25. Two semi-infinite grounded conducting planes meet at right angles. In the region between them, there is a point charge q, situated as shown in figure. Set up the image configuration, and calculate the potential in this region. What is the force on q?



26. A cubical box (sides of length a) consists of five metal plates, which are welded together and grounded shown in figure. The top is made of a separate sheet of metal, insulated from the others, and held at a constant potential V_0. Find the potential inside the box.



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PHYSICAL SCIENCES

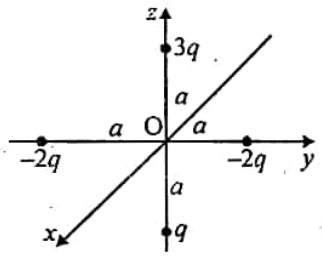
Assignment-03: Electromagnetic Theory

1. Two dipoles with dipole moments $-5\,\hat{z}$ nCm and $9\,\hat{z}$ nCm are located at points (0, 0, –2) and (0, 0, 3), respectively. Find the potential at the origin.

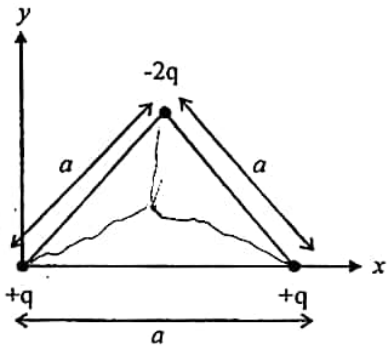
2. An electric dipole with $\vec{p} = p\hat{z}$ C.m is placed at (x, y, z) = (0, 0, 0). If the potential at (0, 0, 1m) is 9V, find the potential at (1m, 0, 1m).

3. A "pure" dipole p is situated at the origin, pointing in the z-direction
   (a) What is the force on a point charge q at $(a, 0, 0)$ (Cartesian coordinates)?
   (b) What is the force on q at $(0, 0, a)$?
   (c) How much work does it take to move q from $(a, 0, 0)$ to $(0, 0, a)$?

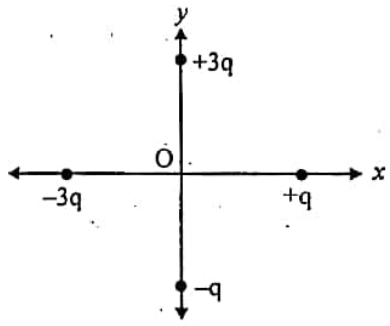
4. Four particles (one of charge q, one of charge $3q$, and two of charge $-2q$) are placed as shown in figure, each a distance a from the origin. Find a simple approximate formula for the potential, valid at points far from the origin. (Express your answer in spherical coordinates).



5. (i)



(ii)



Calculate the dipole moment $(\vec{p})$ of the above charge configurations.

6. A static charge distribution has the form

$$\rho = \rho_0 \left(\frac{r_0}{r}\right)^2 e^{-r/r_0} \cos^2\phi$$

Calculate radial component of the dipole moment of the charge distribution.

7. A sphere of radius R, centered at the origin, carries charge density $\rho(r,\theta) = k\frac{R}{r^2}(R-2r)\sin\theta$, where k is a constant, and r, θ are the usual spherical coordinates. Find the monopole moment and dipole moment for this charge distribution.

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8. The electric potential of a grounded conducting sphere of radius R in a uniform electric field $E_0\hat{k}$ along z-direction is given by the following expression

$$\phi(r,\theta) = -E_0 r\cos\theta + \frac{E_0 R^3\cos\theta}{r^2}$$

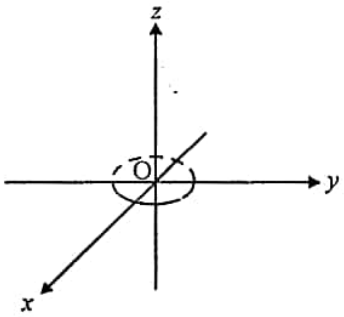
where 'r' is the distance from the centre of the sphere and θ is angle the radius vector makes with the z-axis.
(a) What is dipole moment aquired by the sphere?
(b) Calculate the radial and tangential component of the electric field on the surface of the sphere
(c) What is the surface charge density on the sphere?

9. A spherical shell of radius R carries a surface charge density $\sigma = K\cos\theta$ where K is some constant. Calculate dipole moment of the spherical shell.

10. A circular disc of radius a on the xy plane has a surface charge density $\sigma = \frac{\sigma_0 r\cos\phi}{2}$, calculate the dipole moment of this charge distribution.

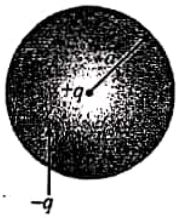
11. A thin insulating rod, running from $z = -a$ to $z = +a$, carries the indicated line charges. In each case, find the dipole moment and leading term in the multipole expansion of the potential:
(a) $\lambda = k\cos(\pi z/2a)$, (b) $\lambda = k\sin(\pi z/a)$, (c) $\lambda = k\cos(\pi z/a)$, where k is a constant.

12. A thin circular ring of radius R lies in the xy-plane with its centre at the origin of coordinates O (see figure). the ring has a uniform linear change density λ.



Find the electric dipole moment $\vec{p}$, about the point O, of the charge distribution.

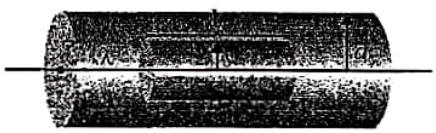
13. A primitive model for an atom consists of a point nucleus $(+q)$ surrounded by a uniformly charged spherical could $(-q)$ of radius a shown in figure. Calculate the atomic polarizability of such an atom.



14. A sphere of radius R carries a polarization $\vec{P}(r) = kr$, where k is a constant and r is the vector from the centre.
(a) Calculate the bound charges σ_b and ρ_b.(b) Find the field inside and outside the sphere.

15. A dielectric cube of side a, centered at the origin, carries a "frozen-in" polarization $\vec{P} = k\vec{r}$, where k is a constant. Find all the bound charges, and check that they add up to zero.

16. A long straight wire, carrying uniform line charge λ, is surrounded by rubber insulation out to a radius a shown in figure. Find the electric displacement.



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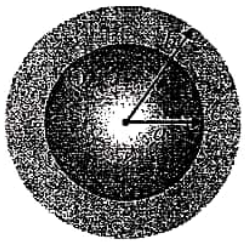
17. A metal sphere of radius a carries a charge Q shown in figure. It is surrounded, out to radius b, by linear dielectric material of permittivity ϵ. Find the potential at the center (relative to infinity).



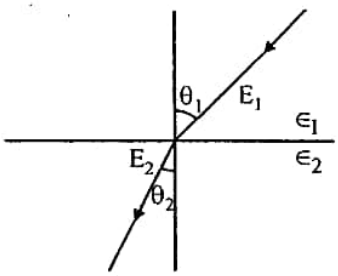
18. A dielectric sphere of radius R has polarization $\vec{P} = kr^2\hat{r}$. Calculate electric field inside and outside the sphere. Also calculate surface and volume bound charge densities and energy of the dielectric sphere.

19. A spherical conductor of radius a carries a charge Q. It is surrounded by a linear dielectric material of susceptibility (χ_e) upto radius b. Find the energy of this configuration.

20. A grounded spherical metal shell inner radius R_1 and outer radius R_2 is filled with uniform volume charge density (ρ) upto R_1. Find the electrostatic energy of the system.

21. A point charge q is imbedded at the center of a sphere of linear dielectric material (with susceptibility χ_e and radius R). Find the electric field, the polarization, and the bound charge densities, ρ_b and σ_b. What is the total bound charge on the surface? Where is the compensating negative bound charge located?

22. At the interface between one linear dielectric and another the electric field lines bend as shown in figure. Show that $\tan\theta_2 / \tan\theta_1 = \epsilon_2 / \epsilon_1$ assuming there is no free charge at the boundary.



23. Two extensive homogeneous isotropic dielectric meet on plane $z = 0$, for $z > 0$, $\varepsilon_{r1} = 4$ and for $z < 0$, $\varepsilon_{r2} = 3$. A uniform electric field $\vec{E}_1 = 5\hat{i} - 2\hat{j} + 3\hat{k}$ KV/m exists for $z \geq 0$ find.

(a) E_2 for $z \leq 0$ (b) $\vec{D}_1$ and $\vec{D}_2$ (c) the angles E_1 and E_2 makes with the interface (d) the energy densities (in J/m^3) in both dielectrics.

24. The region $z > 0$ of a cartesian coordinate system contains a linear isotropic dielectric of dielectric constant 2.0. The region $z < 0$ is the free space. A free space charge density of $5nC/m^2$ is at the inteface $z = 0$. If the displacement vector in the dielectric is $\vec{D}_2 = 3\hat{x} + 4\hat{y} + 6\hat{z}$ nC/m^2, find the corresponding displacement vector $\vec{D}_1$ is free space.

25. Consider the parallel conductors shown in the figure, where V = 0 at z = 0 and V = 100V at z = d. Assuming the region between the plates is charge free. Calculate the potential and electric field between the conductors.

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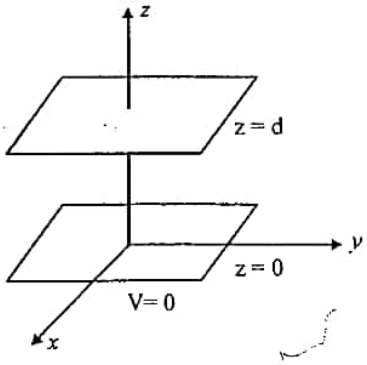
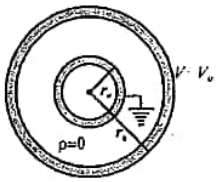
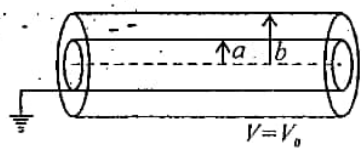


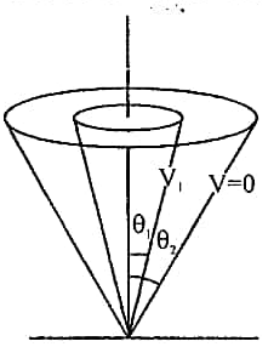
26. Consider two concentric spherical conducting shells at the origin. The outer radius of the inner shell is r_a and inner radius of the outer shell is r_b. If charge density $\rho = 0$ in the region $r_a < r < r_b$. V = 0 at $r = r_a$ and $V = V_0$ at $r = r_b$. Find V in the region $r_a < r < r_b$ by solving Laplace's equation.



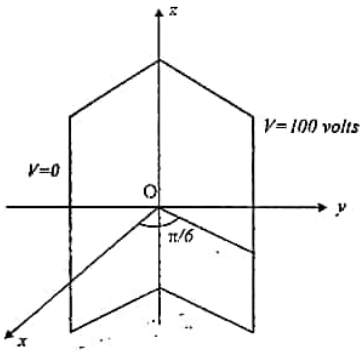
27. Two coaxial concentric cylinder is of radius a and b, if the inner one grounded and outer is at potential V_0. Find potential and electric field between the cylinders by using the laplace equation. Also find capacitance per unit length of the cylinders.



28. Solve Laplace's equation for the region between coaxial cones as shown in figure. A potential V_1 is is assumed at θ_1 and V = 0 at θ_2. The cone verties are insulated at r = 0.



29. Two Semi infinite conducting planes $\phi = 0$ and $\phi = \frac{\pi}{6}$ are separated by an infintesimal insulated gap as shown in the figure. If $V(\phi = 0) = 0$ and $V\left(\phi = \frac{\pi}{6}\right) = 100\ volt$. Calculate V and $\bar{E}$ in the region between the planes.



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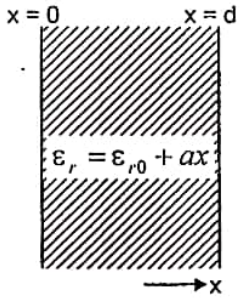
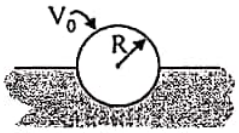
30. Consider a parallel plate capacitor filled with non-uniform dielectric of dielectric constant $\varepsilon_r = \varepsilon_{r0} + ax$. The distance between the plates is d. The free charge on the capacitor plates is Q and plate area is A.

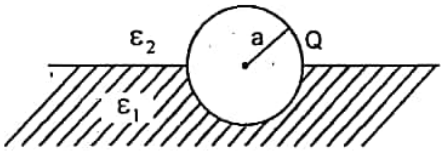


31. A conducting sphere at potential V_0 is half embedded in linear dielectric material of susceptibility χ_e, which occupies the region $z < 0$ as shown in figure.

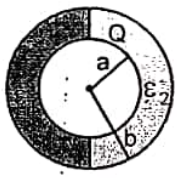


(a) Determine the potential, the electric field and polarization everywhere.
(b) The bound charge, and the free charge distribution on the sphere.

32. A perfectly conducting sphere of radius a and placed at the origin is half embedded in liquid dielectric medium of permittivity ε_1 as shown in the figure if the total free charge on the sphere is Q determine.
(i) Electric field intensity every where
(ii) Surface bound charge density (σ_b).
(iii) Volume bound charge density (ρ_b)
(iv) Free surface charge density (σ_f)
(v) Potential on the surface of the sphere.



33. One half of the region between the plates of a spherical capacitor of inner and outer radii a and b is filled with a linear isotropic dielectric of permittivity ε_1 and other half has permittivity ε_2 as shown in the figure if inner plate has total charge Q and outer plate has total charge –Q, find.



(a) The electric displacements $\vec{D}_1$ and $\vec{D}_2$ in the region of ε_1 and ε_2.
(b) The electric field in the region of ε_1 and ε_2.
(c) The total capacitance of the system.

34. The volume between two concentric conducting spherical surfaces of radii a and b (a < b) is filled with an inhomogeneous a permittivity $\varepsilon = \frac{\varepsilon_0 r}{R}$. Where ε_0 and R are constants. A charge Q is placed on the inner surface and outer one is grounded. Find

(a) $\vec{D}$ for a < r < b, r < a, r > b.
(b) $\vec{E}$ for a < r < b, r < a, r > b
(c) $\vec{p}$ for a < r < b, r < a, r > b.
(d) $\sigma_b|_{r=a}$ and $\sigma_b|_{r=b}$
(e) ρ_b for a < r < b
(f) capacitance (C) of the capacitor.

35. Repeat the above problem for the relative permittivity $\varepsilon_r = \frac{\varepsilon_0}{(1+kr)}$. Where k is some constant.

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Assignment-I: Electromagnetic Theory

1. (d)	2. (a)	3. (b)	4. (a)	5. (b)	6. (a)	7. (c)
8. (b)	9. (b)	10. (c)	11. (b)	12. (a)	13. (b)	14. (a)
15. (b)	16. (a)	17. (b)	18. (b)	19. (a)	20. (d)	21. (c)
22. (b)	23. (a)	24. (a)	25. (b)	26. (a)	27. (c)	28. (a)
29. (a)	30. (b)	31. (d)	32. (c)	33. (c)	34. (c)	35. (b)
36. (c)	37. (a)	38. (b)	39. (d)	40. (a)	41. (d)	42. (c)
43. (c)	44. (b)	45. (d)	46. (b)	47. (a)	48. (c)	49. (b)
50. (c)	51. (a)	52. (b)	53. (b)	54. (b)	55. (c)	56. (c)
57. (d)	58. (c)	59. (a)	60. (d)	61. (b)	62. (c)	63. (d)
64. (a)	65. (d)	66. (c)	67. (c)	68. (b)	69. (c)	70. (b)
71. ( )	72. (c)	73. (d)	74. (c)	75. (b)	76. (d)	77. (a)
78. (b)	79. (c)	80. (d)	81. (b)	82. (a)	83. (b)	84. (c)
85. (b)	86. (a)	87. (a)	88. (b)	89. (a)	90. (a)	91. (c)
92. (b)	93. (c)	94. (a)	95. (b)	96. (d)	97. (a)	98. (b)
99. (c)	100. (a)	101. (a)	102. (d)	103. (c)	104. ( )	105. (a)
106. (d)	107. (d)	108. (b)	109. (d)	110. (a)	111. (b)	

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Assignment-II: Electromagnetic Theory

1. (b)	2. (c)	3. (c)	4. (d)	5. (d)	6. (d)	7. (d)
8. (c)	9. (d)	10. (a)	11. (c)	12. (a)	13. (c)	14. (b)
15. (b)	16. (b)	17. (a)	18. (a)	19. (b)	20. (a)	21. (b)
22. (a)	23. (b)	24. (a)	25. (a)	26. (b)	27. (c)	28. (d)
29. (b)	30. (d)	31. (b)	32. (d)	33. (a)	34. (a)	35. (b)
36. (b)	37. (b)	38. (d)	39. (a)	40. (b)	41. (c)	42. (c)
43. (c)	44. (b)	45. (a)	46. (d)	47. ( )	48. (d)	49. (c)
50. (d)	51. (d)	52. (c)	53. (c)	54. (d)	55. (a)	56. (a)
57. (a)	58. (d)	59. ( )	60. (d)	61. (c)	62. (d)	63. (d)
64. (c)	65. (d)	66. (b)	67. (c)	68. (b)	69. (c)	70. (b)
71. (d)	72. (a)	73. (a)	74. (b)	75. (a)	76. (c)	77. (c)
78. (a)	79. (d)	80. (a)	81. (b)	82. ( )	83. (a)	84. (b)
85. (a)	86. (a)	87. (d)	88. (b)	89. (b)	90. (b)	91. (a)
92. ( )	93. (c)	94. (d)	95. (a)	96. (a)	97. (d)	98. (b)
99_A(a)	99_B(d)	100. (c)	101. (c)	102. (d)	103. (d)	104. (d)
105. (c)	106. (a)	107. (d)	108. (b)	109. (b)	110. (a)	111. (c)
112. (c)	113. (b)	114. (b)	115. (a)	116. (d)	117. (d)	118. (a)
119. (d)	120. (c)	121. (c)	122. (d)	123. (b)	124. (d)	125. (d)
126. (a)	127. (a)	128. (b)	129. (a)	130. (a)	131. (b)	132. (c)
133. ( )	134. (c)	135. (a)	136. (d)	137. (b)	138. (b)	139. (c)
140. (d)	141. (a)	142. (a)	143. (d)	144. (a)	145. (b)	146. (c)
147. (b)	148. (b)	149. (d)	150. (c)	151. (c)	152. (a)	153. (c)
154. (a)	155. (c)	156. (b)	157. (d)	158. (a)	159. (d)	160. (d)
161. (b)	162. (c)	163. (c)	164. (c)	165. (c)	166. ( )	167. ( )
168. (c)	169. (b)	170. (c)	171. (a)	172. (a)	173. (d)	174. (c)
175. (c)	176. (d)	177. (b)	178. (c)	179. (c)	180. (a)	181. (c)
182. (0.15)	183. (d)	184. (c)	185. (c)	186. (a)	187. (d)	188. (c)
189. (b)	190. ( )	191. ( )	192. ( )	193. ( )	194. ( )	195. ( )
196. ( )	197. ( )	198. ( )	199. ( )	200. ( )	201. ( )	202. (c)
203. (a)	204. (a)	205. (b)	206. (b)	207. (d)	208. (b)	209. (c)
210. (d)	211. (a)	212. (c)	213. (b)	214. (c)	215. ( )	216. (a)
217. (a)	218. (d)	219. (b)	220. (a)	221. (c)	222. (d)	223. (b)
224. (b)	225. (1.49 to 1.51))		226. (0.99 to 1.01)		227. (2.3 to 2.4)	
228. (1.41 to 1.47)		229. (c)	230. (10.58 to 10.70)			

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